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CONTENTS

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• • FAMOUS VICTIMS OF WATER BORNE DISEASES

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Vol. 27 APRIL, 1935 No. 4

PRESSURE HEAD IN PERFORATED PIPES

By N. Malishevsky
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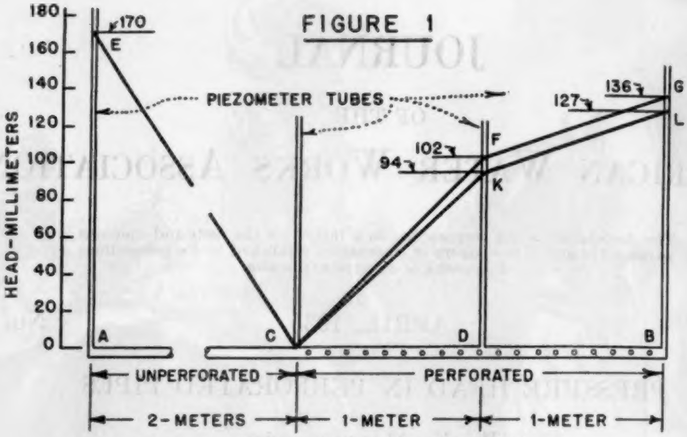
In an effort to provide means whereby the uniform distribution of wash water from the underdrainage system of water filters could be effected and to determine the actual hydraulic conditions of such systems, a series of experiments have been conducted using several sizes and shapes of pipe lines.

In *The Journal* of June, 1927, page 667, an experiment was described relating to the distribution of pressure and velocity head throughout perforated pipe lines used for underdrainage systems in water filters.

In that experiment water was forced through a 2-inch pipe line, marked AB on figure 1. The first 2 meters of the pipe were unperforated, while the last half of the pipe, also 2 meters in length, marked section CB, was perforated with 40–5.5 millimeter orifices, 20 being placed on each side of the pipe. The end of the pipe was capped. During the experiment 3.33 liters per second of water were forced through the pipe. Figure 1 shows two curves for the conditions noted above. Curve EC is for the unperforated portion of the pipe. Curve CKL shows the observed head and CFG the theoretical velocity head. The decreased value of the observed head is due to friction losses. This was less in amount however, than general formulae would indicate. For the conditions of this experiment the

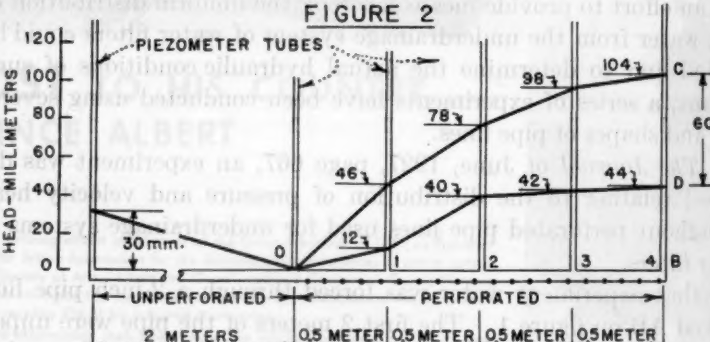
measured loss of head was only 0.01 meter whereas the calculated loss GL was 0.058 meter.

FIGURE 1



PIPE DIAMETER = 50 MILLIMETERS
20 ORIFICES, EACH SIDE, DIAM. = 5.5 MILLIMETERS
Q = 3.33 LITERS PER SECOND

FIGURE 2



PIPE DIAMETER = 63 MILLIMETERS
20 ORIFICES, ALONG BOTTOM, DIAM. = 8.0 MILLIMETERS
Q = 4.45 LITERS PER SECOND

NEW EXPERIMENTS IN 1931

Subsequent to this, further experiments were conducted in the year 1931, to determine the relative friction losses of perforated pipe lines with only one row of orifices compared to pipe lines with two rows of orifices. In the next experiment a pipe 63 millimeters in diameter

was used. Similar to the first experiment, the first 2 meters of the pipe were unperforated and the remaining 2 meters were perforated with twenty 8 millimeter orifices, spaced 100 millimeters on center. All of the orifices looked downward and were arranged in a single row. Five piezometer tubes were placed at 0.5 meter intervals on the perforated tube. The first piezometer was placed ahead of the first orifice and was designated by 0, the second by 1, etc., the last one by 4. The discharge through the pipe was 4.45 liters per second. The results are illustrated on figure 2. The upper curve OC represents the height of the theoretical recovered velocity head, and the lower one OD the observed height of head.

The curves show that the friction loss along the 2-meter length of the perforated tube was 60 millimeters only 30 millimeters along the unperforated 2-meter length. According to existing theories, the loss in the perforated pipe should be only $\frac{1}{3}$ of that in the unperforated portion. In this experiment it exceeded this limit by 6 times, or it was 6 times $\frac{1}{3}$ of 30 millimeters.

A similar phenomenon was observed during the flow of water in a tube with right-angled cross section, see figure 3. This tube was tapered towards the end, the end section being of the same width and only one-fourth of the height. Such a section was chosen because the main drain, or manifold, of rapid sand filters is occasionally made of reinforced concrete with right-angled cross sections. It was interesting to determine how the cross section of the pipe might be changed along its length, so as to avoid the recovery of the velocity head.

If the decrease of the cross section corresponds to the decrease of water flow in the tube, the velocity would remain constant throughout its entire length. It would then be possible to find a section in which the velocity would, nevertheless, decrease. Such a decrease in velocity would result in a certain amount of recovered head. This recovered head could then be accurately measured and completely compensated for by introducing a loss through friction. Then there would be an equal head all along the entire length of tube, and consequently an equal discharge of water through each orifice.

For this experiment a tube 2 meters long, of right-angled cross section was made. The entrance end was 50 by 50 millimeters square and was tapered to 50 by 12.5 millimeters at the far end. The cross section of the far end was, therefore, one-fourth of the area of the entrance end. In one experiment the orifices were made in the side walls, 20 to each side, d = 5.5 millimeters and in another experiment,

FIGURE 3

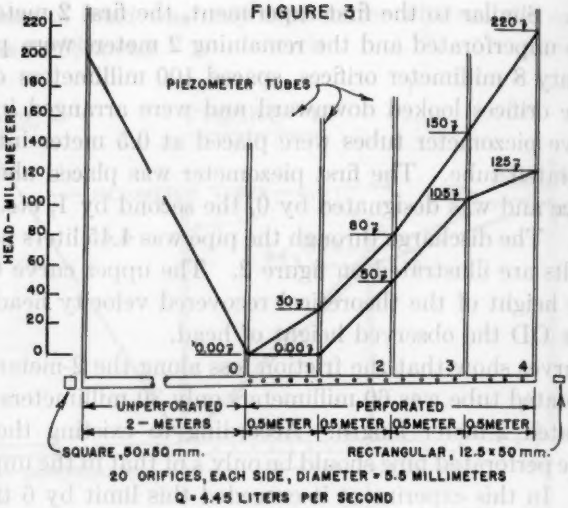
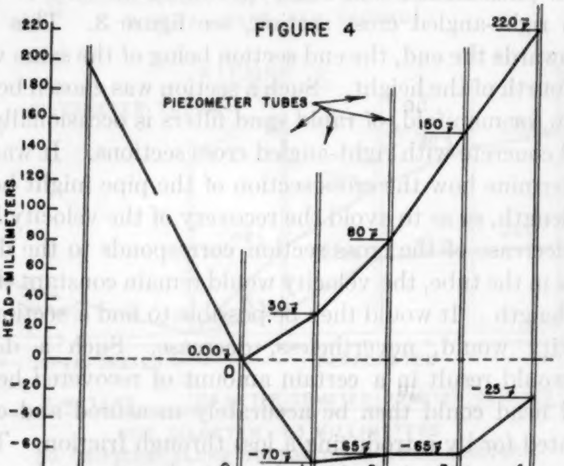


FIGURE 4



one row of 20 orifices were located only in the lower wall, their d = 8 millimeters. The results of the experiment with two rows of orifices are shown on figure 3, and with one row on figure 4. The total discharge in both cases was 4.45 liters per second.

Figure 3 indicates that the loss of head, with right-angled cross section pipes, is much higher than in the round pipes as shown by figure 1. By comparing figures 3 and 4 it is noted that with two rows of orifices the loss of head is much less than with one row. With one row of orifices the loss attains such dimensions, that the pressure in the perforated tube is lower than at the beginning of the tube at point 0. (See figure 4.)

The influence of the arrangement and location of the orifices, 1 or 2 rows, upon the rate of the loss of head in the tubes, as revealed by the new experiments, deserves more careful investigation from a theoretical as well as a practical point of view. Out of these experiments a practical conclusion may be drawn. Such a conclusion is that in drain pipes only one row of orifices is more desirable than two rows. The one row of orifices should be turned downwards so as to produce less recovered head, and consequently, a greater equality of flow than would obtain with two rows of orifices placed on the side walls. Tapering the cross section of the perforated tube effects a decrease of the recovered head, but the reaching of a complete or an almost complete equality of head all along the length of the tube will necessitate supplementary experiments with different tube sections.

M. L. Enger and M. I. Levy in their article "Pressures in Manifold Pipes," in *The Journal*, May, 1929, pp. 650 to 667, draw conclusions quite different from the above-mentioned ones. In their experiments a 2-inch main or manifold had 10 orifices on one side. All of the laterals were likewise 2-inches in diameter and were 36-inches long. The end of each lateral was capped and tapped with a 1-inch hole. When forcing water through this system they found that the velocity head is recovered, less a friction loss, which corresponds entirely to the usual loss in the tubes.

In my experiments quite the contrary was observed. In the round tubes with orifices on both sides, the loss of head was several times less than the usual one, while with the tubes having orifices on one side only the reverse condition obtained, that is, the loss was several times higher than the usual one. This constitutes a new and unexpected element in this phenomenon. The tubes having orifices on two sides indicate a decrease in the loss of head through friction, while the tubes with orifices on only one side increases it as much as in round tubes.

The same phenomenon is still more evident in the experiments with right-angled cross section tubes as shown by figures 3 and 4. The reason for such a striking difference between Enger and Levy's and

my experiments might be explained, perhaps, by the fact that the laterals in their experiments had the same diameters, namely 2-inches, as the manifold.

In my paper in *The Journal*, September, 1928, p. 417, a formula was given to determine the relationship of the maximum and minimum volumes of water discharged through the orifices based on the relation

$$\sqrt{H + \frac{v_1^2}{2g} + \frac{v_2^2}{2g}} : \sqrt{H}$$

in which H is the head at the beginning of the header; V_1 is the velocity in the manifold and V_2 in the laterals.

In view of the data acquired in the more recent experiments it is now desirable to correct this formula on the following basis. If the manifold has laterals on both sides the velocity-head in the manifold is $V_1^2/2g$ and it would be almost entirely recovered at the end with regards to the laterals. The head in the laterals $V_2^2/2g$ is recovered, almost completely, when orifices are on both sides. With orifices on one side only the head is recovered only by 40–50 percent, so the formula would be

$$\sqrt{H + \frac{v_1^2}{2g} + 0.4\frac{v_2^2}{2g}} : \sqrt{H}$$

It is desirable that this be checked for other tube diameters.

UNDERGROUND CORROSION IN THE SOUTHEASTERN UNITED STATES[1]

By K. H. Logan

(*Bureau of Standards, Washington, D. C.*)

In 1932 there were in the United States about 450,000 miles of iron and steel pipe in use underground for the transportation of gasoline, oil, gas, and water. The extent of water mains was estimated at 138,000 miles. In addition there were approximately 13,800,000 gas services. It is not unreasonable to assume that the number of water services is larger. Though not all of the water services are of iron throughout their length a very considerable number of iron water services are in use. The reproduction value of the buried pipes has been estimated at nearly six billion dollars. It is easily seen that with even a small percentage of the pipes in corrosive soils, the losses resulting from corrosion may be very large. In 1933 the Bureau of Standards received from an organization of pipe line operators a resolution regarding underground corrosion work in which the annual losses of that organization attributed to underground corrosion were estimated at over $100,000,000. That industry operates but 25 percent of the underground pipe lines and there is little reason to suppose that its losses per mile of pipe are greater than those of operators of water pipes. This estimate of losses does not include the cost of damage resulting from leaks, which under some conditions is very considerable.

CAUSES OF UNDERGROUND CORROSION

Most scientists now agree that most corrosion at moderate temperatures is an electrochemical phenomenon involving differences of electrical potential. These differences of potential have been attributed to variations in the character of the metal involved, such as mill scale, strains and impurities. It appears, however, that in addition relatively large differences of potential are the result of unequal distribution of oxygen at the surface of the buried metal.

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

Furthermore, differences in the character or concentration of the soil solution at widely separated points along the pipe may also cause corrosion. The effects of these differences of potentials originating in soil conditions so far overshadow those caused by differences in the composition of different rolled ferrous pipe materials, that in the Bureau of Standards tests all of the commonly used pipe materials appear to corrode at nearly the same rates when exposed to the same soil conditions, but at very different rates in different kinds of soils. The importance of the soil in underground corrosion has not been fully appreciated by pipe line operators, and in a number of instances more has been spent for corrosion resistant materials and pipe coatings than was necessary.

CONDITIONS FAVORABLE TO CORROSION

Laboratory experiments indicate that soil corrosion is accelerated by an increase in temperature. We may therefore expect that, other things being equal, the corrosion problem will be more serious in the south than in the north. Although many other things influence the rate of corrosion, experience does indicate that on the average underground corrosion is more serious in the southern states.

While the relation of rainfall to corrosion is somewhat complicated, it is safe to assume that corrosion is accelerated by a plentiful supply of water. In addition to accelerating corrosion by restricting the supply of oxygen the moisture in the soil supplies the path by which the galvanic currents, inseparable from underground corrosion, travel. Very dry soils are usually very poor electrical conductors. The addition of water to dry soil increases its conductivity greatly, but the addition of water to moist soil has little effect.

However, if there is a relatively large amount of water, it fills the space between the soil particles, limits the supply of oxygen and tends to make the supply more uniform. This tends to reduce the potentials causing corrosion. On this account in the laboratory where the moisture is uniform throughout the soil surrounding a test specimen, corrosion losses are less in saturated than in unsaturated soils.

The laboratory condition just specified does not duplicate the condition to which a pipe line may be exposed, since part of the line may traverse a saturated soil while another part is surrounded by soil that is nearly dry. Under such conditions a difference of potential is set up because of the difference in the concentration of oxygen in

the wet and dry soils and corrosion results in the wet soil where the oxygen concentration is least.

The effect of unequal distribution of oxygen has already been discussed. In addition to this relation to corrosion, oxygen has others that tend to restrict rather than to accelerate corrosion. Oxides or hydrated oxides form films on the surface of the metal which may retard corrosion. Hydrous oxides are under some conditions deposited in the pores of the soil and their accumulation tends to restrict the diffusion of air to the metal surface. A porous soil is favorable to the oxidation of corrosion products, but the final effect of this oxidation on the rate of corrosion is not the same in all soils.

Scattered throughout the eastern part of the United States are soils which are acid in their reaction. Serious corrosion of pipes in some such soils has been observed The corrosion is not to be considered as the result of the attack of the metal by the acid since the acid solutions in soils are usually very dilute. The effect of the acid is to retard the precipitation of corrosion products which under favorable circumstances reduce rates of corrosion. Although it is doubtful whether the acidity of a soil can be taken as a criterion of its corrosiveness, because other factors may enter to accelerate or retard corrosion, in the absence of additional information it is probably wise to regard acid soils as corrosive.

In the arid and semiarid regions of the southwest where rainfall is not sufficient to remove the soluble salts from the soil, the electrical conductivity of the soils indicates in a general way their corrosiveness. In localities where the rainfall is heavy, accumulations of salts in the soils are unusual, and soil resistivity measurements are of less value except as a means of locating areas which have been contaminated by factory waste, overflows from deep wells, etc.

CHARACTERISTICS OF CORROSION IN SOME SOUTHEASTERN SOILS

One of the earliest conclusions resulting from the Bureau of Standards soil corrosion investigation was that the form and rate of corrosion of buried ferrous materials ordinarily used for gas and water mains was primarily a function of the soil to which the metal was exposed and nearly independent of the variety of the material. While this statement has been made public on various occasions and has never been refuted by definite evidence, there still remains a large number of pipe users who believe that one variety of pipe is greatly superior to others. The question of the relative merits of pipe

materials is of such importance that all pipe users should know at least in a general way just what the Bureau of Standards data show and something of the reliability and significance of the data.

The similarity in the corrosion patterns is illustrated in figures 1 and 2 which are reproductions of panoramic pictures of Bureau of Standards specimens from five southern soils and a tidal marsh. The conditions of the specimens will be most apparent if the observer faces direct light, holding the top of the pictures nearest the source of light. The numbers at the top of the pictures identify the soils and relate the pictures to the data in table 1.

The top half of figure 1 shows the condition of the wrought iron specimens while the lower half shows the conditions of open hearth steel specimens from the same test locations. The time of exposure

TABLE 1

Weighted average rates of maximum pitting of 10-year-old specimens

SOIL NUMBER	SOIL	LOCATION	WROUGHT IRON	OPEN HEARTH STEEL	CAST IRON
3	Cecil clay loam	Atlanta, Ga.	7.2	6.0	12.8
16	Kalmia fine sandy loam	Mobile, Ala.	6.7	6.4	13.5
22	Memphis silt loam	Memphis, Tenn.	6.8	6.5	15.7
40	Sharkey clay	New Orleans, La.	5.9	6.8	8.8
42	Susquehanna clay	Meridian, Miss.	9.3	12.1	18.7
43	Tidal marsh	Elizabeth, N. J.	12.0	9.5	9.1

was about 10 years. Figure 2 shows the condition of cast iron specimens from the same soils. The length of the specimens and width of the individual pictures was the same for all specimens so that the figures 1 and 2 are directly comparable. They are also comparable with figure 5, but not with figures 3 and 4. It will be noted that the corrosion patterns for different soils differ considerably, but that in the same soil they are quite similar for all three materials. The depth of pits can be compared by consulting table 1.

It has frequently been said that actual experience on working pipes rather than experiments is the true indicator of the relative merits of materials. This is obviously true. The difficulty is in reaching a basis for comparing field data since to yield a correct result all the data must not only be strictly comparable as to time and conditions of exposure, but sufficient in number to eliminate variations attributable to chance.

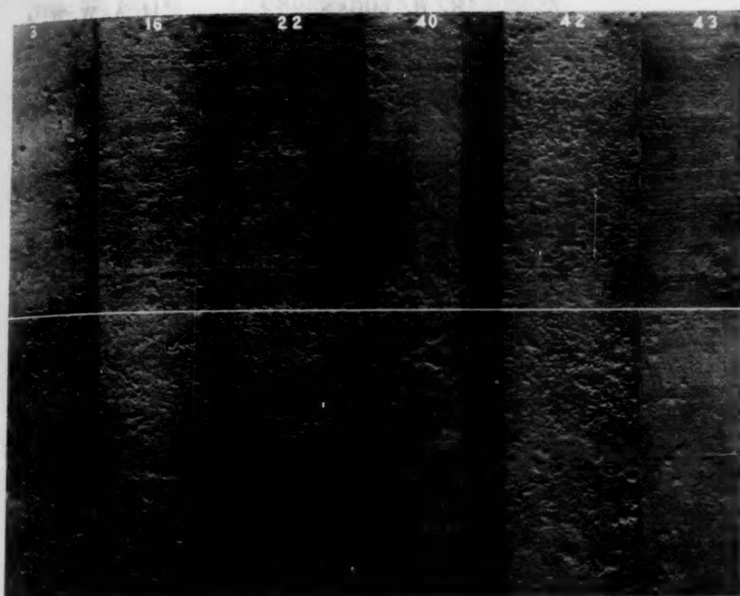


FIG. 1

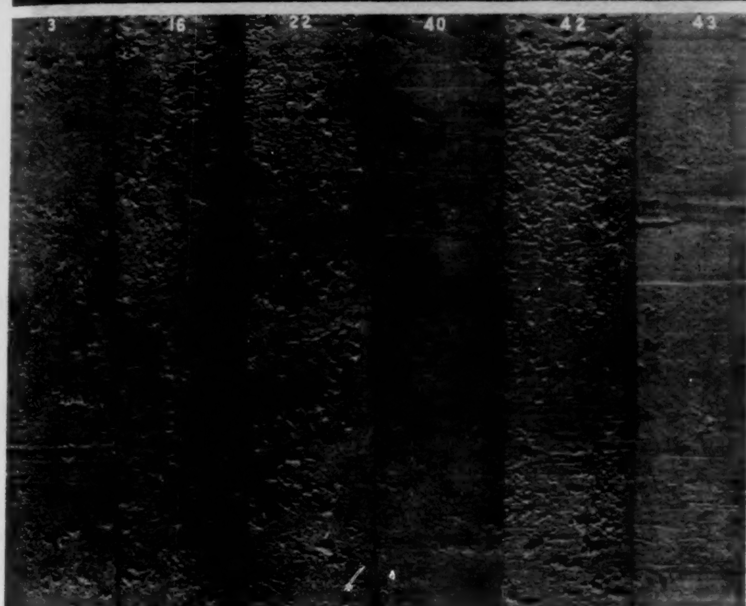


FIG. 2

FIG. 1. WROUGHT IRON (ABOVE) AND BESSEMER STEEL FROM THE SAME TEST LOCATIONS

FIG. 2. CAST IRON FROM THE SAME SOILS AS THE SPECIMENS SHOWN IN FIGURE 1

The unreliability of conclusions based on the comparison of a few observations is illustrated by figures 3 and 4 which permit compari-

FIG. 3. WROUGHT IRON (ON LEFT) AND BESSEMER STEEL (ON RIGHT) IN ST. JOHNS SAND, JACKSONVILLE

sons of 1½ inch wrought iron and Bessemer steel specimens from two Bureau of Standards test sites. In each figure the pictures in the

column on the left are of wrought iron and those on the right are of Bessemer steel. It will be seen that by comparing a picture in the top row with the picture in the opposite end of the bottom row either material may be made to appear better than the other.

Similar results will be obtained if pictures in the same horizontal row are compared. In each figure the deepest pit on the top wrought

FIG. 4. WROUGHT IRON (ON LEFT) AND BESSEMER STEEL IN TIDAL MARSH, ELIZABETH, N. J.

iron specimen is deeper than the deepest pit on the top Bessemer steel specimen, but the deepest pit on the bottom wrought iron specimen is shallower than the deepest pit on the bottom Bessemer steel specimen.

The pit depth data for the specimens are given in table 2.

Figure 5 will be of interest to users of cast iron. The specimens were chosen from a tidal marsh because this procedure permitted the

comparison of more varieties of cast iron. It should be noted that two of the specimens, A and I, were exposed for a somewhat shorter period than were the others. The pit depths shown in table 3 for these specimens are not comparable with those on the specimens shown in figures 3 and 4 (table 2) since it has been shown that for a given period of exposure the larger the exposed area the deeper will be the

TABLE 2

Deepest pits on specimens shown in figures 3 and 4

(These specimens were approximately 10 years old)

FIGURE NUMBER	LOCATION IN FIGURE	MATERIAL	SOIL NO.	NAME	DEEPEST PIT
					mils
3	Top left	Wrought iron	37	St. John fine sand	95.5
	Bottom right	Bessemer steel	37	St. John fine sand	61.0
3	Top right	Bessemer steel	37	St. John fine sand	86.0
	Bottom left	Wrought iron	37	St. John fine sand	46.5
4	Top left	Wrought iron	43	Tidal marsh	102.0
	Bottom right	Bessemer steel	43	Tidal marsh	63.5
4	Top right	Bessemer steel	43	Tidal marsh	77.5
	Bottom left	Wrought iron	43	Tidal marsh	50.0

TABLE 3

Deepest pits on cast iron specimens from a tidal marsh

IDENTIFICATION LETTER	MATERIAL	AGE	DEEPEST PIT
		years	*mils*
A	Southern pit cast iron	8.6	284
C	DeLavaud cast iron	9.9	48
C	DeLavaud cast iron	9.9	298
I	"Monocast" cast iron	8.6	281
L	Northern pit cast iron	9.9	157

deepest pit. The reduction in figure 5 is greater than that in figure 4. Specimens 43 in figure 2 and L in figure 5 are comparable but specimen 43 was an abnormally rough casting. Comparison of the two DeLavaud specimens (C) in figure 5 will make evident the wide range in the rates of pitting possible for two specimens of the same material exposed to nominally identical conditions. A curious fact not shown in the figure is that the DeLavaud specimen having the deepest

pit lost only a little more than half as much weight as the specimen which did not pit so badly. The loss of metal was largely from the inside surfaces which were also exposed to soil. It should be evident from the data just presented that great care must be used in the comparison of corrosion data whether from experimental tests or field observations. The great difficulty in securing data on pipe lines which are

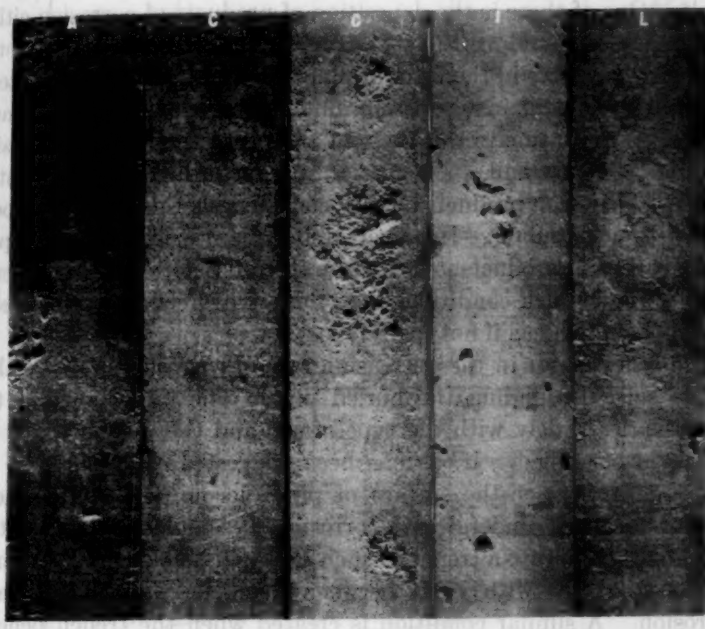


FIG. 5. FOUR VARIETIES OF CAST IRON FROM A TIDAL MARSH

A. Southern pit cast iron. *C.* DeLavaud centrifugally cast iron. Two specimens of same age and exposure. One "Monocast" cast iron L Northern pit cast iron.

strictly comparable makes it necessary to depend largely on experiments for information regarding comparative rates of corrosion.

Soils differ not only in their effects on the distribution of the corrosion but also in rates of penetration. The latter characteristic was shown in table 1 and is illustrated by the curves in figure 6 which show the progress of corrosion in 8 southern soils. The data from which the curves are plotted are the averages of 24 pits on 16 specimens of wrought iron and steel pipe. It will be seen that after 8 years

exposure the average of the deepest pits on the specimens in Norfolk sand (soil 31) was less than half that for the specimens of muck (soil 29).

It will also be noticed that none of the curves taken as a whole is a straight line, but that the slope and curvature decrease with longer exposures, i.e., the rates of corrosion decrease with time but apparently approach a constant value. Two factors aid in producing this result. One of these is the deposition of products of corrosion either in the soil surrounding the metal or on the surface of the metal. Corrosion products in the form of films are quite effective in protecting some metals against corrosion under some conditions. In most such cases the ultimate thickness of the protective film of corrosion products is very small. This is not true for ordinary iron and steel on which corrosion products of very considerable thickness have been known to accumulate. However, under many soil conditions, part of the corrosion products migrate into the soil before they are precipitated. Under such conditions the protective effects of the corrosion products are reduced if not entirely lost.

The other factor in the decreasing rate of corrosion is the settling of the soil surrounding the buried pipe. The importance of this factor varies widely with the type of soil and the way in which the trench is backfilled. If, as has been suggested, differences in the supply of oxygen on the surface of pipes account in a large measure for localized underground corrosion, it should be evident that scraping the soil into a trench in such a way that clods, large or small, rest on the pipe with voids between them, is conducive to rapid corrosion. A similar condition is created when the trench beneath the pipe is not completely filled with soil. While it has often been assumed that the soil will settle and reach an equilibrium within a short time, there are indications that in some soils voids remain at the pipe surface, especially beneath the pipe, for long periods even in localities where the rainfall is abundant. That non-uniformity of the backfill of the trench is a real factor in corrosion is suggested by the fact that, generally speaking, corrosion is more serious on cross country lines where little or no tamping of the backfill is done than in city streets. The fact that corrosion is often worst along the bottom of the pipe can also be accounted for by differences of potential between the bottom and top of the pipe or between points along the bottom of the pipe originating in differences in oxygen supply. It seems desirable therefore that in laying pipes care be taken to secure as nearly as

practicable a uniform contact between the soil and the entire surface of the pipe.

The curves in figure 6 are not only of theoretical interest as suggestive of processes affecting corrosion, but of practical significance also, since they suggest that the common assumption used in valua-

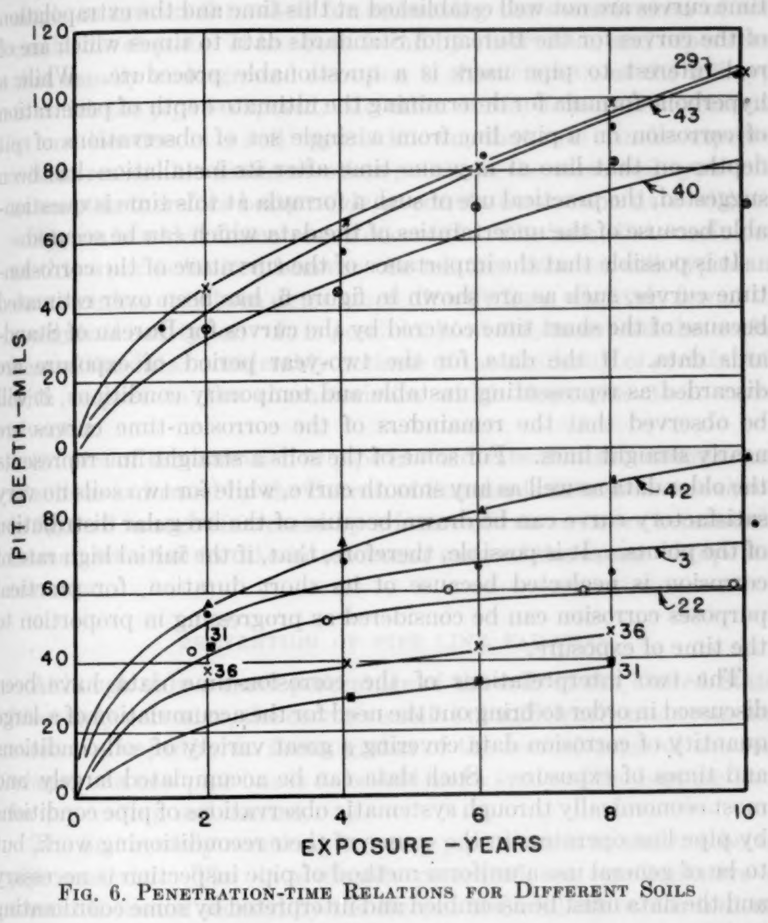


FIG. 6. PENETRATION-TIME RELATIONS FOR DIFFERENT SOILS

tion work, that the depreciation of a line is proportional to its age, is incorrect. Some of the curves indicate that if the wall of the pipe is sufficiently thick to prevent penetration for a relatively few years, the pipe will last indefinitely. This means that if the pipe wall is sufficiently thick there will be practically no depreciation of the pipe line so far as corrosion is concerned. It also means that with such a

wall thickness a protective coating is unnecessary. These possible conclusions depend for their validity on the definiteness with which the corrosion-time curves can be established. Unfortunately, underground corrosion data are not precise and data on corrosion during long periods are few. For these reasons the shapes of the corrosion-time curves are not well established at this time and the extrapolation of the curves for the Bureau of Standards data to times which are of real interest to pipe users is a questionable procedure. While a hyperbolic formula for determining the ultimate depth of penetration of corrosion on a pipe line from a single set of observations of pit depths on that line at any one time after its installation has been suggested, the practical use of such a formula at this time is questionable because of the uncertainties of the data which can be secured.

It is possible that the importance of the curvature of the corrosion-time curves, such as are shown in figure 6, has been over estimated because of the short time covered by the curves for Bureau of Standards data. If the data for the two-year period of exposure are discarded as representing unstable and temporary conditions, it will be observed that the remainders of the corrosion-time curves are nearly straight lines. For some of the soils a straight line represents the older data as well as any smooth curve, while for two soils no very satisfactory curve can be drawn because of the irregular distribution of the points. It is possible, therefore, that, if the initial high rate of corrosion is neglected because of its short duration, for practical purposes corrosion can be considered as progressing in proportion to the time of exposure.

The two interpretations of the corrosion-time data have been discussed in order to bring out the need for the accumulation of a large quantity of corrosion data covering a great variety of soil conditions and times of exposure. Such data can be accumulated largely and most economically through systematic observations of pipe conditions by pipe line operators in the course of their reconditioning work, but to be of general use a uniform method of pipe inspection is necessary and the data must be assembled and interpreted by some coördinating body such as the American Water Works Association, the American Gas Association, or the American Petroleum Institute. Obviously, much more rapid and economical accumulation of data would result from the united effort of these associations with a single organization for the final assemblage and interpretation of the data and distribution of the resulting information.

It has been previously shown that soils differ greatly in corrosiveness. Several methods for determining the corrosiveness of soils have been developed, each of which is useful under some conditions and in some sections of the country. However, the factors affecting corrosion are so numerous and varied that it is doubtful whether a single or universal method for estimating the corrosiveness of soils can be developed. It has been found by observation and experiment that usually underground corrosion is characteristic of the soil type to which the pipe is exposed. In other words, if the rate of corrosion at one location in a soil type is known, that rate can be expected within reasonable limits at other points in the same soil type. An attempt is therefore being made to correlate corrosion data with the soil types in which the corrosion occurred. The immediate usefulness of this work is limited because the relation between soil types and corrosion has only been determined directly for a relatively few of the recognized soil types. It is possible, however, to extend the usefulness of the data considerably because of the similarity of certain soils with respect to the characteristics which determine their corrosiveness.

Studies of the corrosion of pipe line indicate that the corrosiveness of soils as indicated by the Bureau of Standards data such as is shown in figure 6 must be increased by a factor of two or more because the Bureau tests fail to take into account some of the causes of pipe line corrosion.

PREVENTION OF PIPE LINE FAILURES

Although only a small percentage of the soils of the United States is severely corrosive, the corrosive soils are sufficiently numerous and extensive to justify an investigation of the corrosiveness of the soils whenever a new pipe line is to be laid and a study of the best methods for preventing soil corrosion.

The first remedy occurring to many pipe users is to secure a better pipe material. The data already presented are representative of several thousand secured by the Bureau of Standards which indicate clearly that the superiority of any one of the materials under investigation is small. The rates of penetration of pure open hearth iron, wrought iron, Bessemer and open hearth steel and steel containing 0.2 percent of copper, buried side by side in the Bureau test sites, do not show marked differences. Wrought iron, on the average, may be slightly superior to the other materials and cast iron may be pene-

trated somewhat more rapidly, but in most of the soils under investigation the differences are so small as to make it difficult to decide whether or not they are accidental. While some alloys of iron such as Duriron and stainless steel have resisted corrosion very well, there seems to be no immediate prospect of obtaining a ferrous alloy which can be economically used for ordinary underground pipe line construction and, at least for the present, we must seek other methods for reducing corrosion losses.

For installations where the cost of the pipe is but a small part of the entire cost of the installation, as is the case for small services in paved streets, copper, brass, and lead pipe can be used, since under most soil conditions they resist corrosion very well.

Plymetal consisting of a thin layer of corrosion-resistant metal backed by steel to give the required mechanical properties has been suggested as a solution of the corrosion problem, but the cost of such material is still high. Of the metallic pipe coatings which have been exposed to soil conditions zinc has been the most generally used and the most successful. In many cases the failure of galvanized pipe may be attributed to the thinness of the zinc coating or to the injury of the coating by stones, pipe tongs, etc. Pipes coated with zinc at the rate of one ounce per square foot should withstand nearly all soils at least five years before showing signs of rust. The coating will last much longer in many soils. Lead corrodes much more slowly than steel in most soils, but corrosion frequently penetrates several thousandths of an inch which is greater than the thickness of the lead coating frequently applied to pipes. This, together with the facts that at least the older lead coatings were subject to pinholes and that a lead coating does not afford cathodic protection to the iron, has interfered with the popularity of lead-coated pipe for use underground. New lead coatings are being developed which may prove more effective.

The more commonly used pipe coatings are of bituminous materials. The reputation of this class of protection has been injured by unfortunate occurrences which are not necessarily inseparable from its use. Very thin coatings, poor application, and careless handling of the coated pipe have done much to deprive the pipe line operator of the benefits which he might receive from the careful, scientific use of asphalt and coal tar pitch. Moreover, there is a surprising lack of authentic data on the long-time performance of bituminous pipe coatings under well defined conditions. It is therefore impossible to

determine at this time the seriousness of what appears to be some of the defects of this class of materials.

Asphalt base coatings, even when thick, permit enough moisture to reach the pipe surface to form a thin rust film which weakens the bond between the coating and the pipe. Thick unreinforced bituminous coatings tend to flow under the pressure of clods and the weight of the pipe. In some moist soils organic reinforcing materials used to strengthen the protective coating decay.

These things may or may not be serious objections to the use of bituminous pipe coatings. If the decrease in the rate of corrosion shown in figure 6 is the result of the settling of the earth in the trench, all that is required of a coating is the protection of the pipe during the relatively short period of trench instability. If, on the other hand, the corrosion products are mainly responsible for the change in rate of corrosion, rapid deterioration of the pipe in a corrosive soil is to be expected whenever the coating fails and a coating to be satisfactory must retain its protective qualities for a much longer period. Again, the need for more definite information regarding corrosion processes is evident. At present if a bituminous coating material is to be used in a corrosive soil it is probably best to be on the safe side by combining with it a shield or reinforcement of asbestos felt.

Much valuable information concerning the performance of protective coatings will be found in the Proceedings of the American Gas Association and the American Petroleum Institute for the last five years (1929–33).

Recently there has been a revival of interest in cement and concrete as a means of protection against soil action. Extensive data on these materials as pipe coatings are not generally available, but most of the information on them which has been published is favorable. New methods for applying cement to pipe lines have recently been developed that considerably reduce the cost of application.

Cathodic protection as a method of preventing the corrosion of pipe lines was suggested by Clement and Walker in a publication of the U. S. Bureau of Mines in 1913, but little use was made of this method of protection until it was tried on a gas transmission line by the New Orleans Public Service, Inc., in 1930. Since then it has been tried out on several other pipe lines and all users appear well satisfied with the results. The essential feature of the method is the maintenance of the pipe negative or cathodic with respect to the earth by means of a superimposed current usually furnished by rectifiers,

such as are used for charging storage batteries. In order that the current consumed shall not make the cost of operation excessive, the line must be protected by a nearly perfect insulating coating, such as a reinforced bituminous coating, and be free from metallic contacts with uninsulated lines. Such a system was well described by papers presented at the 1933 Convention of the American Petroleum Institute by R. J. Kuhn and by Starr Thayer.

SUMMARY

For the benefit of those who have formed the habit of beginning their reading at the end of a paper, the essential features of this paper are assembled here. As a national problem, underground corrosion results in losses which justify a serious attempt to reduce them. The seriousness of the problem with respect to an isolated pipe system or network depends largely on the soils to which the pipes are exposed.

One of the fundamental and principal causes of underground corrosion appears to be an uneven distribution of oxygen at and near the pipe surface. The ways in which corrosion comes about are so varied that rates of corrosion underground cannot be accurately determined. It follows that it is difficult, if not impossible, to determine accurately the relative merits of pipe materials. The performances of different ferrous materials do not differ sufficiently to permit any one of them to be proved superior by the data now available.

There is urgent need for more definite information regarding rates of corrosion, especially over long periods, in order that the selection of pipe line protection may be put on an engineering basis.

Several methods of protecting pipes are available which appear to be better than those used in the past, but data on their effectiveness are insufficient to place the design of protection for a pipe line on an engineering basis. Again the need is for additional definite data. The economical way to secure data which will change pipe line protection from guessing and forgetting to engineering is through the coöperation of the national public utility associations.

DISCUSSION

Mr. Gibson (*Charleston, S. C.*): Members of the American Water Works Association and water works men in general owe Mr. Logan a vote of thanks for the work he is doing in the Department of Commerce and I sincerely hope our Government in its spasms of saving will not curtail this department's work.

Some of these tests all over the country have been in eight or ten years and some only two years. This test at Charleston has been in only two years but is being continued. I hope Mr. Logan will be spared in health and position to complete these tests throughout the country.

We all have the problem of corrosion. We may not realize it, but it is there, either internal or external. Two things are inevitable, death and taxes. I have recently assumed the responsibility of adding another, the third, and that is depreciation. In depreciation corrosion is a big factor. We have it not only in our mains but in our service pipes as well and, as Mr. Logan says, it does not pay to consider the price of material in this day and time for your service pipe; we should get the best to begin with and that is cheaper in the long run.

Mr. Logan touched upon the point of acid soils and cast iron pipes and we all know we have much trouble in the southeastern section with acid soils.

I am going to give you a few experiences of ours at Charleston. Charleston is a peninsula with salt water on all sides and our lines running in come through the built up marshes that have been filled with mud and about everything else, including old automobiles, cinders, sawdust, and every kind of junk. Pipes buried in that soil give us considerable trouble. Another way of filling those marshes is by pumping in dredged sand and silt. That offers a soil that is very corrosive. We have mains laid by the Government in 1914 to supply the new immigrant station and that main is practically gone. It was laid in soil pumped out of the Cooper River.

In some of our old soils where our pipes are put down in putrid mud we uncover a pipe and we can take an ordinary pocket knife and carve that iron just the same as one can carve a stick. That is graphitized iron and unless it gets a severe shock or vibration I think you can depend on that pipe for years, but the least jar or extra vibration will cause it to break and then you will have lots of expense.

In other soils where the iron oxide is not carried away, we are building up a thick coating of one to one and a half inches of iron oxide on the pipe. With this you will have considerable strength and you will find that when you move the coating of oxide of iron to tap the main it will break as if the oxide of iron gave it strength. In a soil where there is considerable acid but a great deal of motion that coating is carried away and the pipe does not have that protection.

About the painting with coal tar, asphalt or concrete for protection, my idea is that the coal tar is much better than anything else. With an asphaltic coating you will certainly have trouble for asphalt is a peculiar substance. For instance, you can take a very small instrument, say a lead pencil, and scrape on it and you will find that the pencil will penetrate completely through the asphalt going on down to the main body of the pipe. It seems to have no resistance. You will very often find that a pipe coating with a rather thin coating of asphalt will be worn on both the bottom and top and your protection gone, but not so with the coal tar. You will find it the most substantial thing you can use. We have used bitumastic enamel and it seems to be perfect in protecting plates in most instances.

On the subject of doing injury to the coating in the handling during the process of coating or in dipping, we know what that means—trouble. Mr. Logan mentioned the wrapping of the pipes with some form of cloth to hold the coating in position and also mentioned concrete as a possibility. A process has been developed of putting reinforced mortar about the pipes and it is reasonable in price. To me that offers a solution for the protection of wrought iron and steel, but with cast iron pipes we will not be able to do much. I cannot see exactly how we are going to accomplish much unless we have pipe uniformity.

Mr. Logan touched on the fact that, from the series of tests on corrosion by the Bureau, it is difficult to decide whether any of the rolled forms of metals have any decided advantage over the wrought iron, steel, etc.; nevertheless, there is a feeling among the laymen that there is some bit of advantage in the old wrought iron over the modern steel pipes. I do not know whether there is or is not. Sometimes I think there is and sometimes I think there is not.

Recently I had a case of a line laid through an old creek that was filled in. The line was laid about 1880. Those old pit cast pipes were relatively thick, thicker than the modern centrifugal pipes. Some eight years ago I had occasion to lay there some modern centrifugal pipes and I just recently had a break on this line and when we came to examine it the iron was graphitized, you could shave it with a knife, but those old pit cast pipes were in very good condition, although they had been in since 1880. They had a thick coating of rust on them. In that old pit cast pipe there had possibly been an erosion of the metal and that with the sand on the sides had formed

some sort of silicate of iron and we had gotten a tough substance there that was hard to cut with any tool.

My thought is this, study your local problem and use that material you find to give the best results. The best results may not mean necessarily the longer life but perhaps the most economical in the long run. Buy additional protection, even at double price, by buying a material of more thickness. It is far better to have additional thickness so if we do have corrosion we can still have safety.

MR. RAPP (*Atlanta, Ga.*): I have had the opportunity and pleasure of assisting Mr. Logan in the burying and removal of the different classes of pipe and other material on the Atlanta water works grounds. The first of these specimens was buried in 1922. The object of this research is to determine the rate of underground corrosion of the different types of pipe, materials, etc.

A great many different alloys of metal, as well as preservative coatings of different materials were used, as well as unprotected metal. All the chemical and technical nature of this research is fully covered by Mr. Logan's paper and reports on this work.

My observations of the deterioration of these different materials as they were removed, supplemented by forty years of actual installation and renewals of similar pipes and materials in construction work for the Atlanta Water Works, confirm the following conclusions.

(1) In the average municipal water departments, owing to the legal requirement of competitive bidding, specifications for corrosion resistant materials would be useless, as price generally controls the purchase.

(2) The two most important underground structures in a water department are the mains and services. An examination of the different pipe specimens as exhibited by Mr. Logan, that have been buried twelve years, will show that corrosion is apparent on all except copper and brass, and that from a water works standpoint any of the galvanized wrought iron or steel pipe when not affected by electrolysis can be expected to give service from 15 to 20 years, and is suitable for temporary lines and house services where permanent pavement is not contemplated within that length of time.

The life of cast iron pipe is not known and is the best all round material for all sizes of water mains. Corrosion of this material is greatly retarded by proper tar-dip. Recently we removed some 16 and 6-inch cast iron pipe that was made in 1873, sixty-one years ago.

The pipe absolutely showed no sign of corrosion and the coal-tar coating of the pipe is black and glossy. I attribute the condition of this pipe and coating to the purity of the coal-tar available at that time.

My final conclusion is that where permanency and our modern expensive permanent pavement is concerned there is nothing at this time that is better than cast iron pipe for water mains and copper pipe for house services from $\frac{3}{4}$- to and including 2-inch.

The City of Atlanta since October, 1931, has made all taps of the sizes mentioned above of copper, using "stream line" solder fittings. We have placed under ground 2,360 taps and up to the present it has not been necessary to uncover for leaks or renewals of any kind.

MR. HANSELL (*Atlanta, Ga.*): I would like to ask Mr. Logan if they have made any tests of the corrosion effects of sewage on the different pipe materials?

MR. LOGAN: Not that I know of. We are running another test on inner corrosion, but so far we are just working this out. We plan to add chemicals to the water but just how far they have gone in that I am unable to say now.

MR. GIBSON: We have had some pipes carried through manholes where the sewage comes in contact with it. When we have a southeast wind it blows the water back up in there and the sewage backs up in the sewers but we have not had any serious corrosion due to that type of sewage, but of course the industrial waste does serious damage sometimes. We have a number of sulphuric plants where it is almost impossible to keep a line. In some of them we find the pipes completely destroyed in six or eight months, the edge of the pipes have been eaten down until they are as thin as a knife and would cut easily. That plant does not seem to care anything about depreciation, they just accept the inevitable and put new pipes in. The sulphuric acid rapidly attracts cast iron pipes. It is not so much the fresh sewage as it is the industrial sewage that gives trouble.

(Presented before the Southeastern Section meeting, April 11, 1934.)

NITRIFYING BACTERIA IN WATER SUPPLIES

By Douglas Feben

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The bacterial flora of water supplies are greater in number and more diversified in species than is revealed by the methods of routine analysis used in water laboratories. This fact does not lessen the value of the analytical methods or the quality of the water to which these methods are applied inasmuch as the greater number by far of the organisms present are harmless and unobjectionable. In the process of water purification it is possible that a change in treatment may introduce just those conditions favorable to the development of a particular group or species, which may remain unrecognized unless the growth of these organisms is excessive or the end-products of their metabolism is indicated by or interferes with routine tests or analyses, chemical or bacteriological.

Of the many changes and innovations introduced into the art of water purification in recent years, that of ammoniation to prevent the development of chlorinous and chloro-phenolic tastes and odors has received considerable attention and gained many converts, owing to its apparent benefits in a certain number of cases and to the simplicity of its application. Unfortunately, it so happens that ammonia is utilized by the genus Nitrosomonas as a source of growth energy, and their excessive growth resultant from adding ammonia to a water supply is accompanied invariably by the formation of nitrites with its consequent high chlorine demand and interference with the orthotolidine test. The recognition of these conditions, at Detroit, coupled with the fact that these bacteria have received relatively little study, furnished incentives for an attempt at isolation and investigation of their characteristics. The results of this study, incomplete as it may be, are being made the excuse for the presentation of this paper.

It was recognized quite early that free ammonia in a water supply, whether naturally present in the raw water or introduced as a plant process, was oxidized to nitrites, even though the biological nature of this oxidation was not always apparent to the observer. If pre-

ammoniation was the practice this oxidation was found to take place primarily in the filter beds, and in the case of post-ammoniation, the nitrites developed in the distribution system. Campion (1) reporting on the operation of the Barberton, Ohio, plant states

". . . . it was noticed that the filtered water showed a higher color when treated with ortho-tolidine than did the applied water. The applied water after passing through filter paper gave no color with ortho-tolidine, but after running the same water through some of the incrusted sand it gave a color with ortho-tolidine. . . .. from data available it would appear that the nitrogen existing in the reservoir water was gradually oxidized, the oxidation taking place especially in the bed of the filter where the ammonias were changed to nitrites."

Braidech (2) investigating the formation of nitrites says that

". . . . when fresh samples were placed into a clean iron pipe, a progressive increase of nitrite and a subsequent decrease of chlorine and ammonia was noted, indicating probable catalytic influence of the metal in promoting the oxidation of the ammonia by the chlorine to nitrites."

Cox (3) states

"Biological oxidation of a portion of the added ammonia may lead to an appreciable reduction in the ammonia content of the treated water, when the ammonia is added considerably in advance of the chlorine dose, as is the case when ammonia is added to raw water and chlorine to filtered water."

Goehring (4) reports

"When the ammonia was applied to the raw water, reductions varying from 5 to 25 per cent were found in passing through the sedimentation basin. Reductions in free ammonia content of from 40 to 60 per cent were found to take place in the water passing through the filters. . . . From the information on the loss through filters, it is obvious that the ammonia is used up by the bacteria."

Hedgepeth (5) states

"Nitrogen is an essential food element for bacterial growth, and under some conditions nitrites will be formed by bacterial oxidation of the added ammonia nitrogen. Once formed, nitrites will seriously interfere with the ortho-tolidine determination as they will react with the ortho-tolidine to form the typical lemon color which is characteristic of chlorinated ortho-tolidine."

Finally Hulbert (6) conclusively demonstrated this bacterial activity by passing ammoniated water through a column of filter

sand and showed that the presence or absence of nitrites in the effluent depended on the sterility or otherwise of the sand.

Prior to attempting an isolation of the specific organism responsible for this phenomenon, recourse was had to the literature for information on the cultural methods used by previous investigators. It appears that Pasteur was the first to suggest the existence of such an organism and his view was confirmed by Schlösing and Müntz in 1877 and later by Warington. Finally Winogradsky made the isolation in 1891. He apparently realized the obligate autotrophic[1] nature of these bacteria and adopted the principle of elective culture in which the conditions were made unfavorable for the growth of any organism other than those capable of oxidizing ammonia. His original medium consisted of:

Ammonium sulphate	1 gram
Potassium phosphate	1 gram
Tap water	1 liter

Small portions of this medium were placed in flasks and inoculated with soil. When nitrification took place a transfer was made to a flask of fresh media. When several such transfers had been made, he seeded a plate of the same media solidified with silicic acid gel, and several days incubation produced small microscopic colonies.

METHOD OF GROWING ORGANISMS

Without attempting to enumerate the several trials made with varying degrees of success, a brief description will be given of the method found most satisfactory in this study. The composition of the culture medium used is as follows:

	gram
Ammonium sulphate	1.0
Potassium phosphate (dibasic)	1.0
Magnesium sulphate	0.5
Sodium chloride	2.0
Magnesium carbonate	Excess
Distilled water	1.0 liter

20 cc. portions of this medium are distributed in 50 cc. test tubes, plugged and sterilized. The ammonium sulphate is sterilized as a separate solution and added afterwards with a sterile pipette. The

[1] Autotrophic—growth in absence of organic matter.

resulting pH of this medium is between 8.0 and 8.4. Most authorities stipulate that the magnesium carbonate should be basic, but the normal carbonate was used in this work with excellent results. This substitution was made because the basic carbonate was found to contain sufficient nitrites to inhibit the growth of the organisms sought.

The tubes of sterile media were seeded with raw water and incubated at 28 to 29°C. (82 to 84°F.) in a slanting position to provide greater liquid surface area. This is essential for rapid development, as these organisms obtain their carbon supply from atmospheric CO_2. Growth of the nitrifying bacteria can be demonstrated indirectly by testing for nitrites, and directly by streaking a prepared plate of solid media with inoculum from a culture tube. In the former method, the culture is filtered directly into a 50 cc. Nessler tube and the precipitate washed with distilled water to make up the filtrate to 50 cc., and the nitrite nitrogen concentration is then determined by the method given in Standard Methods of Water Analysis. The quantitative determination so obtained is multiplied by 2.5 to give the concentration in the media prior to dilution by washing. It was found unnecessary to make a number of successive transfers to gain enrichment as any culture tube found positive as indicated by a strong nitrite reaction, yielded typical colonies on solid media. Inoculating a tube with a pure culture of these organisms produced an increased nitrite nitrogen concentration of 0.2 p.p.m. in 12 days incubation.

Control tubes were incubated with every batch of seeded tubes, and all cultures were tested for purity by inoculating into nutrient broth, total absence of growth indicating the required purity.

In the search for a suitable solidifying agent for the culture media, the silicic acid gel method of the original investigators was discarded as calling for too much time and requiring considerable skill and technique in its preparation. The washed agar successfully used in growing obligate autotrophic bacteria was adopted in this study. It was obtained from the Difco Laboratories who prepare it especially for use in the Noble's cyanide citrate agar. This special agar is prepared from the standard material by giving an initial 24 hour soaking in distilled water followed by four successive washings. The product from this treatment is practically free from soluble organic matter and mineral salts. In preparing the solid media it was found best to omit the magnesium sulphate since this served to

form a double salt with ammonium, which crystallized out very quickly, especially in the line of contact of the inoculating needle, and rendered examination of colonies difficult. When pouring the plates, the sterile ammonium sulphate solution was first introduced into the Petri dish and the agar containing the remainder of the requisite mineral salts was poured in by decanting the clear supernatant fluid, leaving the excess of magnesium carbonate in the flask.

Streaking a plate of this medium from a culture tube will produce colonies visible to the naked eye in two to three days, and seven to ten days incubation will give colonies 1 mm. in diameter if not too numerous.

Two species of bacteria were isolated by the cultural methods described. One gave colonies which are small, flat, lobate, and brownish in color, with a dull appearance. Under a low power they appear as finely granular with faint striations. A stained preparation shows them to be short, fat rods and motility could not be demonstrated. Introducing pure cultures of this organism into liquid media failed to produce nitrites and no further work was done to identify or describe them.

The nitrifying bacteria produced small, circular, entire, capitate colonies, which appear as small drops of a glistening whitish fluid by reflected light and by transmitted light they are transparent with a brownish tinge. Morphologically they are small gram positive cocci about 0.5 microns in diameter. A hanging drop preparation never revealed motility. When the edge of a freshly prepared hanging drop is examined, it can be observed that the surface tension drawing the cells towards the edge, lines them up in orderly rows, each cell being surrounded by six others. The cells never appear to be in intimate contact however, suggesting the appearance of being surrounded by an invisible envelope, which if rendered visible would probably double the apparent diameter of the cell. This envelope or membrane must be of a gelatinous nature as the cells tend to clump into zoogleal masses, this latter condition being especially marked in a stained preparation. Several capsule stains were tried in an attempt to demonstrate this exterior structure of the cell, but with negative results.

Success with the cultural method just described, made the enumeration of Nitrosococci in the raw water from the Detroit river a simple matter. Planting a geometric series of dilutions at various times indicate from 10 to 1000 per cc. of this species.

LOCATION OF BACTERIAL GROWTHS

Since the filter bed appears to be the seat of most active nitrification, the sand from a freshly washed filter was examined for these bacteria. Taking all necessary precautions against contamination, one gram of drained but moist top sand was weighed into a sterile bottle and shaken vigorously for five minutes with 10 cc. of sterile tap water. Nitrifying organisms were recovered from suitable dilutions of this suspension to indicate a concentration of approximately 1,000,000 per cc. A little thought will show that a filter bed receiving ammoniated water, offers a nearly ideal environment for the natural growth and multiplication of these bacteria. The sand grains become coated with aluminum hydroxide, an inorganic gelatinous substance in which the Nitrosococci become imbedded. Organic matter, if present, is highly diluted, and the bacterial growths, besides being continuously washed of their inhibitive waste products, are receiving an uninterrupted supply of nutrient salts.

Under such conditions it is not surprising that the filter effluent contains these organisms which, if they survive post-chlorination, are carried into the reservoirs and distribution system, there to avail themselves of any opportunity for aftergrowth. That such is the case was proven by isolating the organism from tap water samples. The accompanying table, showing tests all made on the same day, effectively illustrates the results of their activity through the entire system.

Water sample	*Residual chlorine, p.p.m.*	*Nitrite nitrogen, p.p.m.*
Applied	0.15	Trace
Filtered	0.02	0.05
Weir	0.08	0.0
Tap 1	0.04	0.003
Tap 2	0.0	0.002
Tap 3	0.0	0.005
Tap 4	0.0	0.100

This water has been treated with ammonia added in the form of sulphate mixed with the alum, the trace of nitrites in the applied water partially indicating the nitrification through the settling basin, as some of the nitrites formed have been oxidized to nitrate by the pre-chlorination. The 0.15 p.p.m. residual chlorine in this sample is undoubtedly chloramine since free chlorine and nitrites cannot coexist. Most of the pre-chlorine is literally wasted in oxidizing

nitrites formed in the filter bed as indicated by the filtered water chlorine residual of 0.02 p.p.m. This residual is again existant as chloramine since there is also present a nitrite nitrogen concentration of 0.05 p.p.m. The weir sample represents the plant effluent shortly after receiving a 0.3 p.p.m. dose of post-chlorine and the measured residual of 0.08 p.p.m. is apparently a mixture of free chlorine and chloramine since all the nitrites have been oxidized, and there remains sufficient NH_3 for further nitrite production in the distribution system. One part of nitrite nitrogen requires about five parts of chlorine for oxidation, and five times the nitrite nitrogen concentration in the filtered water indicates its chlorine demand, namely 0.25 p.p.m. The 0.3 p.p.m. dose of post-chlorine added to the 0.02 residual in the filtered water is 0.32 p.p.m. so that the 0.08 residual in the weir sample represents a loss of 0.24 p.p.m. of chlorine, which checks with the theoretical amount required by the nitrites in the filtered water. The sample marked Tap 1 was collected close to the high lift pumps and the samples marked Taps 2, 3 and 4 represents samples collected at distances in the distribution system of approximately 2, 6 and 8 miles respectively. The complete loss of chlorine and the increased concentration of nitrite indirectly demonstrates continued growth of nitrifying bacteria in the tap water.

From plant results it appeared that chlorine is not an effective germicide for this specific organism. In order to demonstrate this a pure culture was used for an experimental determination of chlorine resistance. Tubes were prepared containing 10 cc. of chlorine solution of varying strengths. These solutions were made by adding pre-determined amounts of a standardized chlorine solution to sterile tap water with a zero chlorine demand. A suspension of the bacteria was prepared and diluted to a point where a 2 mm. loopful introduced into the 10 cc. solutions gave a concentration of approximately 100,000 per cc. This concentration was determined initially by the Breed method and afterwards checked by dilution and plating. One loopful of inoculum was removed from each of the inoculated dilutions at definite time intervals and introduced into suitable culture media. No attempt was made to determine the percent reductions of bacteria, so in order to gain a relative picture of their resistance a duplicate test was run in parallel using B. Coli. The cultures of both species were originally isolated from pre-chlorinated water and presumably represent chlorine resistant strains. The results are given in table 1.

As seen from the above table, no B. Coli were recovered from the

chlorine concentrations in excess of 0.2 p.p.m., whereas Nitrosococci were recovered from all. The activity of the latter organism was progressively reduced in the concentrations in excess of 0.5 p.p.m., but given sufficient incubation time they recovered their activity in full.

A final point of interest to the bacteriologist is the possibility that these nitrifying bacteria are not soil organisms as has been presupposed. Carey and Waksman (7) have isolated similar bacteria from sea bottoms and conclusively proved that this is their native habitat and are not introduced by contamination from the land. A more complete study may show that the Nitrosococci described in this paper are also indigenous to the waters from which they were isolated, and if so, would add considerably to our knowledge of the bacterial flora of surface water supplies.

TABLE 1

CONTACT TIME	CHLORINE CONCENTRATIONS, P.P.M.															
	0.05		0.1		0.2		0.5		0.8		1.0		1.5		2.0	
	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
minutes																
2.5	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−
5.0	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−
7.5	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−
10.0	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−
12.5	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−
15.0	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−
20.0	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−
30.0	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−
60.0	+	+	+	+	+	+	+	−	+	−	+	−	+	−	+	−

N = Nitrosococci. C = Coli.

Summarizing briefly it can be stated that

(a) Great Lakes water (and presumably all surface waters) definitely contain nitrifying bacteria, of an undetermined species.

(b) Artificial methods of culture are simple and direct.

(c) Sand filtration after ammoniation promotes their growth during suitable water temperatures to a point where the chloramine process defeats its own purpose and becomes

costly due to wasting of both ammonia to feed the bacteria and chlorine to oxidize their products.

(d) Their resistance makes it appear impossible or impractical to control nitrification by chlorination.

(Presented before the Central States Section meeting, August 24, 1934.)

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A REVIEW OF ELIZABETH CITY'S STRUGGLE FOR AN ACCEPTABLE WATER SUPPLY

By J. C. Parker

(*Superintendent, Public Utility Commission, Elizabeth City, N. C.*)

The first public water supply in this city consisted of a two wheel cart, bearing a large barrel tank fitted with a form of sprinkler, similar to what is now used for oil treating our highways, only it was more or less shakily constructed and held in place by wires. This crude apparatus was drawn in most cases by a steer. The tank was filled from the river and the water used to sprinkle the streets in front of the stores, the owners paying some small fee for this service. Those not paying were, of course, not accorded the service, so the street often looked like a checker board, being alternately wet and dry.

Sometime in the middle nineties, one Joseph Sanders, then operating a buggy factory and machine shop on Poindexter Street, obtained the first franchise to lay pipes in the streets for conducting water to prospective users. This service was available for street sprinkling, so most of the merchants installed garden hose and did their own sprinkling. The saloons, some fifteen in number, were also users of this water system.

In 1902, one Neal Ferebee obtained from the city franchises for almost every form of public utility, surely several that even today could hardly operate in cities anywhere nearly as small as Elizabeth City. Out of this conglomeration of franchises, only the Power, the Water, and the Sanitary Sewer Companies survived, or in fact, were hardly contemplated.

The Water Company, the only one we are interested in, acquired the property of the Sanders Water Company, and was put into operation in 1903, obtaining its supply from a shallow well some 12 feet wide and 200 feet long and 7 or 8 feet deep with a very coarse gravel bottom. The water was drawn from the well by two large duplex steam pumps and forced into a 70 foot stand pipe from which it flowed directly into the pipe lines. The pumping plant was located adjacent to the Electric Generating Station on Pennsylvania

Avenue and was connected with the well by about ¾ mile of 10-inch cast iron suction line. Since the well failed to furnish a suitable water, it was abandoned in favor of a slow sand filter of some 2000 feet in area. Like the well this water was unsuitable and was later abandoned.

Attempts were made to get good water by building deep wells, but after drilling to a depth of over 1500 feet and finding only salty water, the well job was also abandoned.

Then the Water Company turned to Knobbs Creek for its supply. This creek flows into the Pasquotank River from a drainage basin of some 30 to 40 square miles of swamp, farm and wooded area, forming the center section of Pasquotank County.

Using Knobbs Creek water, it was necessary to treat and filter, so a small wooden tub filter was installed and the water treated with alum and lime or soda ash. There is no record to show just the nature of that finished water. At any rate the demand for water was increasing and the old wood tub filter capacity was sorely taxed, so about 1919, the company built a two section modern rapid sand filter, capable of handling approximately one million gallons daily of any ordinary raw water, but not Knobbs Creek water. With the new filter and settling basin very good water could be produced at times, but at other times with the alum and lime treatment, it was just impossible to produce suitable water, and we had to use a colored water or have water with a large amount of free alum available. "The color was very much preferred to the alum."

At this time, it is advisable to state that the Water Company had spent quite some money and employed skilled water works chemists, and of course, had the assistance of the State Board of Health. I do not believe any other plant in the state caused Mr. Miller and Mr. Catlett so much trouble.

CITY TAKES OVER WATER COMPANY

This brings us up to the time of the acquirement of the Water Company by the City in February, 1925, and of the building of the present filter plant, which is modern in every detail; but with this last word in filter plant equipment (put into operation in 1927), the Knobbs Creek water at frequent intervals was just as prone to treatment as it was in the old filter. Mr. Olsen was Consulting Engineer on the construction and Mr. Hedgepeth was Plant Superintendent and Chemist. Not being able to see the bottom of the clear water

reservoir, was a slap in the face, so to speak, so after a long study and many experiments a treatment was perfected that would produce a favorable water at any time, provided the duration of settling time could be prolonged. In other words, if we could wait long enough we could get good water. Unfortunately or fortunately, the public did not care to wait and so during the dry summer and fall months with fairly good water available it was frequently the case that our storage basins would be practically empty and very frequently the daily consumption was greater than our production. It was apparent that something had to be done to correct this condition. The question of metering was taken up and this started a long drawn out series of discussion and study of the metering problem from almost every source of information. We wrote letters, examined reports and questionnaires, compiled data and finally assured ourselves that metering all consumers was the proper course to take. We were then producing an annual average of 1.25 million gallons per day.

METER INSTALLATION

Work was started on the meter installations in the fall of 1930 and a marked drop in plant pumpage was immediately noticed. In a great many installations defective plumbing was found and underground leaks were located. The former were the principal causes of waste, yet several cases were found where residences used over 20,000 gallons per month and their plumbing was in excellent shape. The net results of our metering program was that our pumpage was cut down to 600,000 gallons per day, effecting a saving in power and purification cost amounting to approximately $6,000 per year on a total cost of meters and installations of about $34,000.

With the change in the water treatment it was possible to treat up to one million gallons daily with almost any kind of raw water, but at times when the demand exceeded that amount the water was bad, so the installation of the meters practically doubled the available plant capacity in addition to effecting the saving in purification and pumping costs. There was a slight drop in the revenue collected after meters were installed, but this was more than offset by the saving in power and chemicals.

CHLORIDES

Up to this time, I have refrained from mentioning chlorides, but to the people of this town and more particularly to those of us con-

nected with the water department, chlorides are spelled with all capitals. They have been the cause of more than one sleepless night. We have tested and measured depths and distances up and down the river and Knobbs Creek, trying to locate their source. We have built dams, and redammed, and then redammed them, but to no avail. When we have dry spells of any duration at all, we have had salt in Knobbs Creek and more salt in the river.

During these protracted droughts the river becomes salty for many miles above the city and the water often reaches a chloride content of over 5,000 p.p.m. Knobbs Creek above the dam only had a capacity of about 50 days normal usage and with a small difference of level the water from the river seeped into the creek reservoir through the underground sand strata. In order to stop this seepage, it would be necessary to construct a steel sheet dam several thousand feet long extending down to the clay at an average depth of about 25 feet and then in order to store sufficient water, would require extensive dredging. On account of the very flat surface of the surrounding farm lands, it would be very risky to attempt to store water behind a dam that would even give us one foot additional water. The danger of backing up water and spoiling growing crops in the spring would be far too great and the nature of the water would not be changed and a change in the source and nature of the raw water had become apparent.

ANALYSES OF WATER

At about this time it was decided to make a thorough and final analysis of the three available waters, namely, the Knobbs Creek reservoir, the deep well and the surface well or shallow well sources. We appealed to the State Department of Conservation and Development and through them to the U. S. Geological Survey. Mr. Ray and Mr. Bryson of the Department of Conservation and Development and Mr. Thompson of the Geological Survey came down and went over the grounds and laid plans for a comprehensive study of possibilities to effect a permanent relief from our troubles. As a result of this visit a contract was entered into whereby the Federal Department furnished the men for this survey on a fifty-fifty basis, the City paying one-half salary and expenses and the U. S. Geological Survey, the remainder.

Following the confirmation of this agreement, Mr. Lohman, junior geologist, came down and spent several months investigating the

shallow ground water storages over this entire section and more particularly that section immediately west of the city.

DEEP WELL

At the same time we were drilling a deep well near the filter plant with the idea of settling for all time the frequently offered idea of deep wells as a remedy for our water problem, but as was expected, the water at 80 to 90 feet was too salty and the next stratum, at 480 feet, was far too salty, having 3,000 parts chlorides. This stratum of very salty water has been sealed off and the 80 foot stratum developed with an 8-inch well and pumping equipment has been ordered. The idea is to use this water only in emergencies.

DECISIONS ABOUT WATER

After another lapse of several months during which time the shallow ground source was under observation and after exhaustive tests to determine the use and necessary treatment, it was decided to use the top water stratum, which is a very fine sand bed from 12 to 18 feet thick immediately under the top or surface soil.

To get the water from this bed, it was decided to construct a gravel well and after placing a little over forty tons of fine gravel and not then getting a sand free water the gravel well was abandoned. This well produced about 60 g.p.m. We next installed nine driven well points, 2 inches by 5 feet with 60 mesh brass screen wire strainers in a battery and pumped on these and was able to get a sand free water and safely pull 7 or 8 g.p.m. per well without uncovering the strainer.

DRIVEN WELLS

This set of driven wells was pumped for several months and a very accurate record of pumpage, rainfall and ground water elevations in the immediate area and at distant points was logged The results of pumping tests and samples of sand together with measurements of the extent of same were taken to Washington and were reported on by the department. They advised that there was suitable water within the area of certain test wells and that there was ample water under certain conditions, it only being necessary for us to install sufficient well points in large enough area to furnish our requirements.

Our next move was to install on a farm we had purchased enough wells to give our requirements with each well being pumped at ap-

proximately 7 gallons per minute. We put in 60 wells, therefore, or about one well per acre. So far, this installation has more than met our expectations, but the possibility of pumping a large quantity of water for a short emergency period and the possible withdrawal during a very extensive dry spell warrants an addition to the present field. Arrangements are being made now to take care of this new extension.

Mr. Wm. Piatt of Durham was Consulting Engineer on this job and designed the lay-out of wells and the pumping equipment.

We have experienced very little difficulty in the operation of the system as installed and it is furnishing ample water for our present needs.

PAPERS CONCERNING TREATMENT OF OUR WATER

It is not amiss to cite you to the following papers previously published in technical journals concerning treatments of our water from Knobbs Creek source:

Color Removal with Sodium Aluminate at Elizabeth City, N. C. Water and Light, July, 1928. L. L. Hedgepeth.

Chlorinated Copperas, A Novel Coagulant. Jour. Amer. W. W. A., October, 1928. W. C. Olsen and L. L. Hedgepeth.

E. S. Hopkins, Industrial and Engineering Chemistry, 21, 58, 1929.

Unusual Color Removal Plant, by Carl C. Wilson. Jour. Amer. W. W. A., May, 1931 (Discussion).

The Removal of Organic Bound Iron From a Highly Colored Water. Jour. Amer. W. W. A., July, 1933. T. R. McCrea.

Coagulants Used in Water Purification and Why." Jour. Amer. W. W. A., September, 1934. L. L. Hedgepeth.

(Presented before the North Carolina Section meeting, November 12, 1934.)

OPERATING ECONOMIES EFFECTED THROUGH INSTALLATION OF SMALLER PUMPING EQUIPMENT

By E. R. Tull

(*Superintendent, Water Department, Rockingham, N. C.*)

A large saving in pumping costs has recently been affected at the Rockingham, N. C. Water Plant by the installation of a smaller pumping unit. The circumstances of this change present a graphic illustration of what might be accomplished by replacing obsolete pumps with efficient equipment of the proper size. It has also demonstrated the fact that obsolescence may be due to causes other than physical depreciation or being superseded by newly developed equipment of higher efficiencies.

There are perhaps many similar cases where the operating conditions of a plant have been vastly altered by economic developments or structural changes to the plant, leaving a pump in operation which is much too large for the requirements. These conditions sometimes exist because they have been overlooked or not considered of sufficient importance to justify investigation.

In filter plant operation interest is naturally centered on the proper treatment of water to produce a wholesome and potable product. While emphasis is placed on maintenance of the plant equipment, the pumping unit is often considered too specialized to invite a search for potential economies. Consequently, it is not surprising that the possibility of pumping economies sometimes does not receive the enthusiastic endorsement which might be accorded a suggestion for savings in chemicals.

Then again, considerable difficulty is sometimes experienced in convincing the city officials of the economic advantage of buying a new pump to replace one in use that is in good mechanical condition and entirely adequate for the needs. In this respect relative efficiencies are often inclined to lose their effectiveness when expressed in percentage.

Similarly, due to the apparently complex character of the contracts with the Power Company that source of possible economy is often ignored entirely. However, by reason of the varying conditions

controlling the rates and fixed charges of a particular load that field should afford considerable investigation with the idea of an improved arrangement providing a better power rate. Establishing a new power demand charge was the most important factor in making such a large reduction in operating expenses at the Rockingham Plant.

This plant was designed to supply about 400,000 gallons of water daily, and for this purpose was equipped with a 750 g.p.m. centrifugal pump driven by a 75 HP induction motor. Under these conditions the first year's operation was considered entirely satisfactory. As pumping was against a 210 foot head an average pumping cost of $35 per million gallons was accepted as reasonable.

Unfortunately the plant was to operate only a year at its rated capacity as one of the largest consumers contracted with a competing water company for service. With the loss of this customer the output was cut almost in half. For the next few years the pump was in service only about 5 instead of the 10 hours a day formerly required and the power bill fell from $400 to $300 per month. It is of particular significance to note that, although only half as much power was consumed for pumping, the cost of power decreased only one fourth due to the fixed demand charge and relative sliding scale rate of the Power Company of the 75 HP motor. The result was an actual increase in pumping costs, from $35 to $50 per million gallons.

Realizing that the power bill had not decreased in proportion to the amount of water pumped, some of the city officials were yet doubtful of the consistency in buying a new pumping unit when the one in service was comparatively new and in perfectly good condition. Since the merits of such a change evidently should have to be proven before its adoption, the logical procedure was to assemble actual data for comparison in order to point out the decided advantages of a unit of the proper size.

COMPARISON OF PUMPING ALTERNATIVES

Test runs were made to determine the pumping rate and the power demand necessary to meet the plants requirements adequately. The tests indicated that the pumping time could safely be increased from 5 to 12 hours daily, consequently reducing the rate of pumping from 750 to 300 g.p.m. Under these conditions the 75 HP motor could be replaced by a 30 HP motor.

From the Power Company it was ascertained that by substituting

a 30 for the 75 HP motor the power demand charge could be reduced by the amount of the difference and at the same time throw a larger block of power in the lower brackets of the rate scale.

Thus, instead of the 80 HP demand charge of $120, including the first 3200 Kwh (which is equivalent to 3.75 cents per Kwh) and the next 4000 Kwh at 2.5 cents and so on down the scale, a 37 HP demand charge of $52.50 would include only 1480 Kwh at the highest rate and the difference would be moved on down into the cheapest class. By pumping only 200,000 g.p.d. by the larger motor not enough power was consumed during the month for any to fall in the range of the lowest rate. The saving thus to be effected was estimated to be about $60 per month.

This would amount to $720 a year and of course would be the minimum yearly saving, since pumping efficiencies would undoubtedly be improved by having new equipment, a decreased volume through the mains and other factors. It was estimated that the desired unit could be installed near this figure.

NEW INSTALLATION

In locating the proposed unit it was deemed advisable to install the unit as near the clear-well as possible rather than inside the plant building in order to conserve space and to lessen the suction lift and eliminate several ells in the suction line for a further increase in efficiency.

A representative of a pump manufacturer then presented these data before the board of city commissioners which, after thorough consideration, purchased a 300 g.p.m. Ingersoll-Rand centrifugal pump direct connected to a 30 HP G.E. Squirrel-cage induction motor. The unit was installed by the town force at a total cost of $680.00.

The new pump has now been in operation nearly two years and the results have been most gratifying. Comparison of bills prior and subsequent to the installation show a monthly saving of approximately $115 to $125. The new unit had paid for itself within six months operation from savings in costs of power. Pumping costs have been reduced from $50 with the former pump to $30 per million gallons with the new unit. This is even $5 per million gallons less than the original setup when the plant was operating at rated capacity.

In addition to the economies affected it was possible to equip the

small unit for automatic operation at a nominal sum, thereby eliminating the almost constant supervision formerly necessary. It also makes it possible to maintain normally a full storage tank as further protection in case of fire or breakdown. The cost of equipping the large pump for automatic control would have been comparatively prohibitive.

There are probably many instances where a little investigation will show conclusively that the pumping equipment could be replaced by a smaller unit with resulting savings in operating costs and very often improving the operating conditions.

Most of the reputable pump manufacturers have capable sales engineers available who are anxious to offer valuable and dependable information relating to the comparison of economies and arrangements of different types of units. Excellent coöperation is also to be expected from the Power Companies whose contracts are governed by the particular load demands of an installation. With the assistance of these two important sources of information it is not difficult to determine whether a different arrangement might not be profitable.

(Presented before the North Carolina Section meeting, November 13, 1934.)

TASTE AND ODOR CONTROL AT COUNCIL BLUFFS

By Wm. T. Bailey

Chemist, Water Department, Council Bluffs, Ia.

The treatment for removal or prevention of tastes and odors usually consists of one or more of the following:[1,2]

1. Aeration
2. Pre-chlorination
3. Super chlorination followed by de-chlorination
4. Ammonia and chlorine
5. Powdered activated carbon
6. Granulated activated carbon filters
7. Potassium permanganate
8. Copper sulphate
9. Fullers earth or bleaching clay
10. Ozone

Of these treatments the ones most commonly used are aeration, ammonia-chlorine, pre-chlorination, powdered activated carbon and copper sulphate.[2]

The type of treatment selected is naturally influenced by the source and nature of the taste or odor, efficiency and cost of the treatment and the limitations imposed by the physical structure of the plant on the application of the various methods.

Causes of tastes and odors are sometimes divided into the following headings;[2]

1. The presence of organisms and vegetable matter in the raw water.

2. Industrial wastes and domestic sewage.

3. Dissolved gases such as hydrogen sulphide.

To these I would add a fourth; growths of organisms in open reservoirs.

In many of the older water purification plants, such as our own, the clarified water is retained for hours and even days in open reser-

[1] Report of Committee on Control of Tastes and Odors in Public Water Supplies, J. A. W. W. A., 25: 1490–1504.

[2] R. A. Irwin, Taste Control of Water Supplies, J. A. W. W. A., 26: 1202–1213.

voirs. Such reservoirs furnish excellent opportunity for the growth of algae and other organisms which may impart their own peculiar tastes and odors to the water. Or, on being destroyed by treatment with copper sulphate, they may decay and impart a putrefactive odor to the water.

It is possible to remove or prevent the formation of most tastes and odors by the proper combination of treatment and by using a sufficient quantity of chemicals, although in some cases the cost may be quite high[3] and in extreme cases the production of a potable water may be well nigh impossible.[4]

DESCRIPTION OF COUNCIL BLUFFS PLANT

Under conditions of normal flow the raw water taken from the Missouri river at Council Bluffs does not carry sufficient organic matter or industrial wastes to cause any great difficulty. What tastes and odors are present are generally seasonal; ordinarily being present only during the annual "spring run off." The past few years of low rainfall and the resulting low river stage have increased the concentration of industrial wastes sufficiently to cause difficulty on one or two occasions. The same conditions have produced much heavier algal growths along the tributaries of the Missouri. The subsequent emptying of these growths into the river have frequently necessitated treatment for the removal of these algae and their essential oils in order to prevent tastes and odors appearing in the finished water.

Since we do not filter the turbid Missouri river water our reservoir capacity is necessarily much greater than would be found in a filtration plant. After coagulation the water flows through a series of 8 open reservoirs before it is pumped into the distribution system. At a 4 m.g.d. consumption this gives a theoretical retention of approximately seven days where the turbidity of the water varies from 1 to 30 p.p.m. In addition to these an elevated reservoir floats on the distribution system with an additional 24 hours theoretical capacity. With the water thus exposed to sunlight ideal conditions exist for algae, bacteria, protozoa, etc., to thrive unless some means of prevention is used.

[3] H. F. Blomquist, Operation at Cedar Rapids, J. A. W. W. A., 25: 716.

[4] E. L. Lium, Experiences With Dwindling Water Supplies in Northwestern Minnesota and the Results of Unusual Dosages in Water Treatment, J. A. W. W. A., 26: 150.

TREATMENT

Prior to 1926 the only treatment used for controlling these growths was the periodic application of copper sulphate by dragging in sacks along the reservoir walls. This intermittent treatment was found to be very unsatisfactory as the growths would no sooner be checked in one place than they would appear in another. As a result the water carried a fishy or pigpen odor much of the time, and the action of chlorine, used in sterilizing the water, upon these organisms frequently resulted in medicinal tastes in the tap water. Enormous increases in the bacterial content of the water coming from these reservoirs always followed the copper sulphate applications, and unsightly masses of algae were present on the surface of the reservoirs much of the time during the summer months. "Dead end" flushing was a regular procedure.

During June, 1926, experimental treatment was tried at the primary coagulant house, using liquid chlorine to control these growths. It was found that 0.8 to 1.0 p.p.m. liquid chlorine seemed to stop the growths almost completely in the coagulation basins and apparently helped in checking those in the clear water basins. No chlorinous taste resulted from this treatment.

On the basis of this experiment electrolytic cells for generating chlorine by the electrolysis of a salt solution were installed in the primary coagulant house. These were used during the summer months of 1927 and 1928 and were then replaced by a dry feed chlorinator.

The treatment during the summers of 1927 and 1928 merely checked the growths in the coagulation basins. Certain forms of algae, mainly Oscillatoria and various Diatoms, developed a tolerance for the chlorine treatment. When the growths became so extensive that they threatened to impart tastes to the water either copper sulphate treatment was resorted to or the basins were emptied and washed.

In the spring of 1929 all basin walls were sprayed with a copper sulphate solution, hoping to prevent attached forms of algae getting a foothold. Chlorine treatment was begun at the primary coagulant house May 15 instead of June 1 as had been done previously. Copper sulphate treatment was increased to the amount used prior to the chlorine treatment.

For some reason the suspended matter in the raw water responded more readily to coagulation that year with the result that the tap

water turbidity was considerably lower during July and August than during the same months of 1928. The algae treatment seemed to check growths of green and blue-green forms but the diatoms developed a resistance to the treatment in the clear water basins. Because of the unusual clarity of the water a very heavy growth took place over the bottoms of these basins, where previously they had merely extended a few feet down the walls. In mid August the water level was lowered three or four feet. The decrease in pressure was sufficient to permit these brown, gelatinous growths to tear loose from the bottom and in a few hours time all three clear water reservoirs were covered with masses of diatoms which, so far as size, shape and color was concerned, resembled army blankets. The clear water basins were immediately bypassed, emptied down the sewer and washed.

Copper sulphate was the only treatment used on the high level storage reservoir up to this time. In fact it was not even emptied and washed from 1924 to 1928. When it was emptied for washing in June, 1928, nearly two feet of black muck was found on the bottom, resulting from the decay of leaves blown into the reservoir and from algal growths killed by the copper sulphate treatment. This reservoir has been washed from two to four times a year since that time.

When the writer took charge of the purification of the Council Bluffs water supply in February, 1928, he asked that all calls concerning the quality of the water be referred to him for investigation. He also took over the hydrant flushing in order to familiarize himself with conditions in the distribution system. It was found that practically all complaints of tastes came from the vicinity of "dead ends," which are quite plentiful in Council Bluffs by virtue of the topography of the city, and areas of poor circulation. In flushing these hydrants it was observed that usually a small amount of greyish sediment came from them, followed by practically clear water for several minutes and then came a stream of foul smelling, blue-black muck. After this was removed the water became clear once more and remained clear. It was necessary to flush these areas at intervals of from two to four weeks in order to prevent complaints, and the writer spent practically half of his time flushing hydrants during his first three years with the Department.

One day when flushing one of these hydrants a lady stopped to watch the proceedings. When the blue-black muck began to pour

out of the hydrant she remarked, "and just to think that we drink that water."

After a few such experiences we firmly vowed to remove the cause of all this stagnation if it were at all possible.

During 1929 samples were collected for bacterial analysis from houses where complaints of tastes had been registered. At the same time a large number of samples were taken from the surface of the elevated reservoir which floats on the distribution system. The summary of these tests is shown in table 1.

The results of these tests were very alarming, as it was evident that from a standpoint of B. Coli content the water was actually unsafe, although the tests taken at the plant showed it to be satisfactory at that point. It was evident that the elevated reservoir

TABLE 1

Summary of bacterial tests, 1929

SOURCE OF SAMPLES	BACTERIA PER CUBIC CENTIMETER ON PLAIN NUTRIENT AGAR		B. COLI AND B. AEROGENES PARTIALLY CONFIRMED TEST ON EOSINE METHYLENE-BLUE AGAR	
	24 hours incubation at 37°C.	48 hours incubation at 20°C.	Percent 1 cc. tubes	Percent 10 cc. tubes
Tap at pumps	29	44	0.67	2.23
City samples	190	3,890	2.5	20.5
Elevated reservoir	344	6,344		44.7

was responsible for the bacterial condition, so a solution feed chlorinator was installed to feed chlorine into the water as it entered the reservoir.

This installation was made March 1, 1930 and chlorine was added to the water in the reservoir at the rate of from 1 to 11 pounds daily, endeavoring to maintain an ortho-tolidine residual of 0.1 p.p.m. as the water came from the reservoir.

Ortho-tolidine residuals were first used for controlling chlorine dosage at the pumping station in 1928. Previous to this time the dosage was controlled by the findings of the bacterial tests; these were now used to confirm the control by residuals.

A 20 percent increase was made in the chlorine dosage in the primary coagulant house for algae control in 1930. Although no chlorinous tastes appeared coming from the pumping station, a

great many came from the vicinity of the elevated reservoir during the time when the application at that point was greatest.

While the bacterial summary for the year of 1930, table 2, shows the water to be passing the Treasury Department standards, 31.6 percent of the 10 c.c. portions taken from the elevated reservoir during June and 16.2 per cent of those taken in July showed the presence of the Colon-aerogenes groups. From 12.5 to 20 percent of the 10 c.c. tubes from City taps showed the presence of this group during June, July, August and September.

This variation in percent tubes showing the presence of the Colon-aerogenes organisms was found to be due largely to two factors. One was the poor circulation in the elevated reservoir, and the other was failure to sterilize new mains that were laid. These conditions

TABLE 2

Summary of bacterial tests, 1930

SOURCE OF SAMPLES	BACTERIA PER CUBIC CENTIMETER ON PLAIN NUTRIENT AGAR		COLON-AEROGENES GROUP PARTIALLY CONFIRMED TEST ON EOSINE METHYLENE-BLUE AGAR	
	24 hours incubation at 37°C.	48 hours incubation at 20°C.	Percent positive 1 cc. tubes	Percent positive 10 cc. tubes
Tap at pumps	34	40	0.15	0.35
City samples	155	327	1.8	5.6
Elevated reservoir	57	121	0.7	5.5

were remedied by placing a forty-five degree bend on the vertical inlet, which is also the outlet, of the elevated reservoir, and arranging for the application of hypochlorite to new mains, under the supervision of the Chemist.

The increase in chlorine dosage at the primary coagulant house aided in materially controlling algal growths, although copper sulphate applications were necessary at times. The reservoirs were washed in mid-summer, and in September free floating forms of algae appeared in the clear water basins in sufficient numbers to produce a medicinal taste with the chlorine applied as the water entered the mains; necessitating washing at that time.

A regular inspection and flushing of all hydrants in the system in early spring and late fall was begun in 1930, and is still carried out. The interval between flushing of "dead ends" was appreciably length-

ened, sufficiently so to assure us that we were started on the right track.

Since we had not been able to find any residual chlorine in the coagulation and clear water reservoirs, excepting near the point where chlorine was applied, ammonium sulphate was applied in the mixing chamber ahead of the chlorine at the primary coagulation house during the summer of 1931. By using 1.00 to 1.25 p.p.m. chlorine and applying 4 pounds ammonium sulphate to 3 pounds chlorine a residual of 0.15 p.p.m. was maintained at the outlet of the secondary coagulation basins during the entire summer. This had completely disappeared by the time the water had passed through the clear water basins. An attempt to increase this residual by applying chlorine at the inlet of the clear water basins failed to meet with any success; the ammonia apparently having been used up by algae.

The ammonia-chlorine treatment kept down growths of all algae in the coagulation basins with the exception of micrococcus forms which seemed to develop a tolerance to chloramine. When this happened the reservoirs would be treated with copper sulphate.

Bacterial tests for 1931 merely showed a lower B. Coli content than in 1930, probably due to better circulation in the elevated reservoir and the sterilization of new mains.

Hydrant flushing and reservoir washing were carried out as in the previous year.

The dry feed chlorinator was replaced with a solution feed machine of greater capacity in the spring of 1932, with the intention of increasing the dosage of chlorine and ammonia sufficiently to carry a residual through the clear water reservoirs. During May, 1932, the raw water turbidity rose to 25,000 p.p.m., and the turbidity at the primary coagulation house rose to 10,000 p.p.m. The chlorine application was then made ahead of the coagulants in order to assist in floc formation. The required chlorine dosage was so great with this turbidity that the chlorinator was moved to the secondary coagulation house to be used for algae control and since that time we have relied on copper sulphate entirely for controlling growths in the first two primary coagulation basins.

No equipment was available for applying ammonium sulphate except at the primary coagulant house, and an attempt to apply ammonia so far ahead of the chlorine immediately resulted in a great increase in algal growths in the primary coagulation basins.

Program for control of mains and hydrant flushing

We then decided upon a definite plan for reducing stagnation in mains and hydrant flushing, working along three lines:

1. The reduction of the amount of sediment entering the distribution system by reducing the tap water turbidity from an average of 5-7 parts per million to as low as we could get it by continuous use of double coagulation. Prior to that time the secondary coagulation house was used only during periods when the water was difficult to coagulate.

2. Ph control of the lime treatment was begun in order to correct corrosion in the distribution system, certain sections showing a great deal of rust when hydrants were flushed. Since that time we have carried the pH at from 7.8–8.2, depending on the alkalinity.

3. The chlorine dosage was increased to 1.5–2.0 p.p.m. at the secondary coagulation chamber. Since the turbidity at this point was normally about 15 p.p.m. we hoped to oxidize any organic matter present in the water. This treatment actually gave a color reduction of 10 p.p.m. much of the time it was used.

As a result of this heavy chlorination a residual of from 0.5 to 1.00 p.p.m. was found after 8 hours contact. We then decided to try application of ammonium sulphate after the chlorine treatment in sufficient amount to form chloramine with this residual chlorine; thereby getting the bleaching effect and also carrying the residual further in the reservoirs. By this method we were able to get a residual of 0.35 p.p.m. entering the first clear water reservoir, but it was dissipated before reaching the outlet of the third clear water reservoir.

Again we found the micrococcus form of algae, which the writer believes to be Cosmarium, gradually developing where this residual chloramine was 1.00 p.p.m. The same form became so luxuriant in the clear water reservoirs that frequent applications of copper sulphate were necessary, which ultimately resulted in putrefaction taking place on the bottoms of these reservoirs and necessitating emptying and washing them.

However, from the standpoint of stagnation in the distribution system the treatment was so successful that we were able to discontinue flushing hydrants from June 1, until the time of inspection of all hydrants in October.

Bacterial results were greatly improved during 1932, no B. Coli

being found in samples collected from the City taps, and but 1.5 per cent of the 10 c.c. tubes on samples taken from the elevated reservoir showing this organism.

The mean tap water turbidity for the year was 4.88 p.p.m., although it was below 2 p.p.m. much of the time during the summer months. The average turbidity for the period of the "spring run off" was 15 p.p.m. This led to a study of coagulation which resulted in the installation of baffles in both coagulation chambers. The result was that the mean tap water turbidity for 1933 was 3.2 p.p.m. and the mean for the first ten months in 1934 is 1.6 p.p.m. At the same time, by comparison of coagulant dosages with other plants along the Missouri river, an estimated saving of $1900 for coagulants was made during 1933.

Activated carbon

No changes in the application of taste control treatment was made during 1933 until September. At this time the secondary coagulation reservoirs suddenly developed a strong odor as of tankage, which was greatly enhanced by the oxidizing action of the chlorine.

No attempt had been made to use powdered activated carbon up to that time, as most of our difficulties were originating in the reservoir system. In view of the poor coagulation during the "spring run off," we hesitated to use carbon because of the belief that we would be unable to remove the carbon satisfactorily from the water without filtration.[5] This condition called for immediate action, so a wire was sent for a rush shipment of Aqua Nuchar. While the Nuchar was coming the secondary coagulation basins were emptied and washed. Despite the fact that a residual chloramine of 1.25 to 0.75 p.p.m. had been maintained through these basins the entire summer the sludge was very putrefactive and gave off the tankage odor; which was believed to result from packing houses upstream dumping tankage in the river. When the Nuchar arrived it was first applied ahead of the primary coagulation at the rate of 25 pounds per million gallons. The ammonium sulphate was then applied before the chlorine at the secondary coagulation house. The odor immediately disappeared. After a few weeks time the point of application of the activated carbon was shifted to the outlet of the second primary coagulation basin, the point where it is still applied. Here the turbidity was only 15–25 as against 100–700

[5] L. R. Howson, Potability of Water, J. A. W. W. A., 26: 1151.

p.p.m. at the point where it was first applied. The result was that we were able to reduce the dose to 10 pounds per million gallons.

With the exception above mentioned the results were practically the same as in 1932. The application of ammonia and chlorine was extended over the entire year for giving better bacterial control than when depending on chlorine alone at the pumping station, using greatly reduced treatment after the temperature of the water dropped to below 50 degrees Fahrenheit.

But one flushing of "dead ends" was necessary between the spring and fall inspections. Very few reports of tastes were received, and but one 10 c.c. portion of water collected at the pumping station showed the presence of B. Coli. Not a single sample collected from taps over the City and from the elevated reservoir showed B. Coli.

Algal growths made their appearance in the clear water reservoirs and the elevated reservoir in midsummer as before, and were subjected to the customary copper sulphate treatment and reservoir washing.

Because of the excellent results obtained with activated carbon it was used again when the ice went out of the river in 1934. However, once we began using it we were obliged to continue its use during the entire summer as a decrease in dosage invariably resulted in complaints of tastes. This, we believe, was due to the fact that the extreme drought and low river stage gave much greater concentration of organic matter, particularly algal oils, and perhaps barnyard wastes, following the infrequent rains. In early summer a cloudburst in Sioux City was followed in two or three days by a very decided putrefactive odor in the reservoirs. The carbon treatment was not increased sufficiently to remove all of this and some complaints of odors in the distribution system resulted. This was corrected by increasing the carbon treatment.

A solution type chlorinator and a dry feed ammoniator were installed in July, 1934, to give a second application of chlorine and ammonia as the water enters the clear water basins. These basins were emptied and washed in order to completely free them of algal growths and the treatment begun as they were refilled. Before they were emptied the residual chloramine was 0.50 p.p.m. at the inlet of these basins and had completely disappeared when the outlet was reached. Sufficient chlorine and ammonia were applied, using 1 part ammonia to 3 parts chlorine, to increase the residual from 0.50 to 1.10 p.p.m. The residual at the outlet of the clear water basins

remained at 0.65 to 0.75 the rest of the summer, and most of the time no chlorine was applied as the water entered the mains. No complaint of chlorine taste has resulted from this high residual, which has now increased to 1.00 p.p.m. with the drop in temperature which has recently taken place, the tap water temperature now being 45 degrees F.[6]

There are still some algae which build up a resistance to these high residuals. In addition to the form which has been identified as Cosmarium, another form, thought to be Sphaerocystis, appeared in August, 1934. Both forms were readily removed by light treatment with copper sulphate, although the Sphaerocystis developed so rapidly once it started that the reservoirs began to have a grassy and fishy odor before copper sulphate was applied.

Copper sulphate applications were made at the elevated reservoir once a week in addition to the application of from four to eight pounds chlorine daily. Despite this treatment some algal growths took place. These became extensive enough to be noticeable by the time this reservoir was washed on October 31, although no complaints resulted from them.

The high chlorine residual entering the mains had dropped to a maximum of 0.20 p.p.m. entering the elevated reservoir most of the summer. At the outlet the maximum was 0.05 p.p.m. Since the reservoir was washed the maximum residual entering the reservoir has been 0.60 p.p.m. and the residual on the water leaving the reservoir is 0.30 p.p.m.

One thing noticeable with our treatment during the past summer is the effect of activated carbon on the micrococcus growths of algae. Whenever enough carbon was applied to darken the water no algal growths took place in the reservoirs where the carbon remained in suspension. Apparently the carbon shut off the sunlight sufficiently to prevent algal growth taking place.

Another very striking effect of the carbon treatment is the stabilization of the sludge in the three coagulation basins and two of the clear water basins where it is found in sludge. This fact, together with the almost complete freedom from algal growths has permitted us to dispense with washing clear water basins No. 1 and No. 2 this

[6] (Author's note.) Chlorinous tastes developed with residual chloramine above 0.50 p.p.m. upon discontinuing activated carbon shortly after presentation of this paper. This would indicate that complete removal of organic matter is necessary in order to prevent chlorinous tastes with chloramine residuals above 0.50 p.p.m. in cold water.

fall. The washing of all clear water basins and secondary coagulation basins should be reduced at least 50 percent in the future.

With the exceptions of two or three of the worst offenders no dead ends were flushed between the spring inspection, which took place in April, and the fall inspection, which started in late October. Practically all of them were found to be completely free from the evil smelling, blue-black muck.

COMPARISON OF BACTERIAL RESULTS

A summary of bacterial examinations made during the first ten months of 1934 is shown in table 3. The average of bacterial counts in 48 hours incubation is 39, as against 3,890 in 1929, for samples collected from the City taps. For samples collected from the elevated reservoir the average 48 hour count is 20 per c.c., as against

TABLE 3

Summary of bacterial tests, first 10 months, 1934

SOURCE OF SAMPLES	BACTERIA PER CUBIC CENTIMETER ON PLAIN NUTRIENT AGAR		B. COLI AND B. AEROGENES PARTIALLY CONFIRMED TEST EOSINE METHYLENE-BLUE AGAR	
	24 hours incubation at 37°C.	48 hours incubation at 20°C.	Percent 1 cc. portions	Percent 10 cc. portions
Tap at pumps	9	16	0.00	0.00
City samples	20	39	0.00	0.00
Elevated reservoir	10	20	0.00	0.00

6,344 in 1929. Not a single sample collected from the elevated reservoir, not a single sample collected from City taps, and not a single sample collected from the pumps showed the presence of either B. Coli or B. Aerogenes during this ten month period. In fact so few 10 c.c. tubes show the presence of lactose fermenting bacteria that we are planting 50 c.c. portions in lactose broth instead of 10 c.c. portions.

Another source of much worry was the presence of large numbers of "pin point" colonies appearing at certain seasons on the plates made from the tap water, and which were always ignored in making bacterial counts. These are completely absent since using the present method of treatment.

Previous to the use of ammonia and chlorine for controlling algal growths we were troubled a great deal with Cyclops in the clear water

reservoirs. Not a single one has been found since ammonia has been used.

In fact, the treatment we are now using for control of tastes and odors (figure 1) is so satisfactory that with the season just past, which was unquestionably the most conducive to algal growths and tastes and odors in general that we have experienced at our plant, we had the least trouble from this source in our experience. The only change we contemplate is the addition of ammonia at the elevated reservoir.

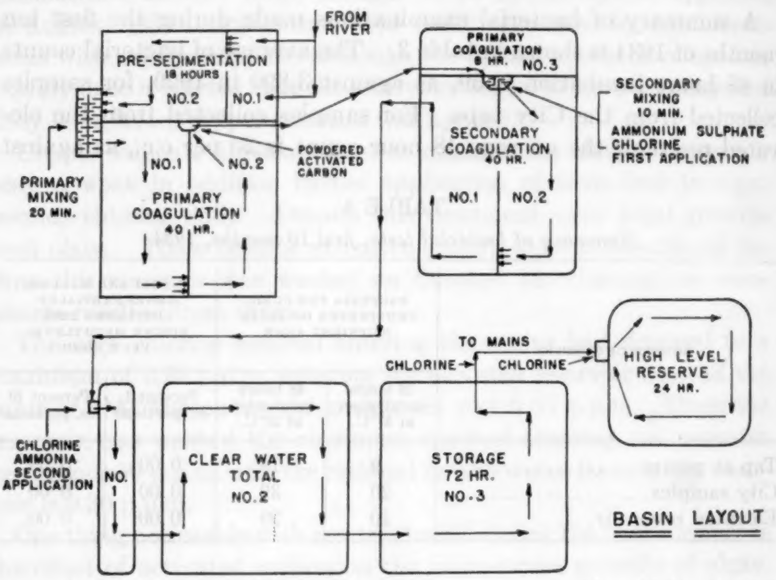

FIG. 1

SUMMARY

1. Ammonia-chlorine treatment is superior to chlorine treatment for controlling algal growths in open reservoirs where long detention periods follow the application. A residual chlorine of 0.50 p.p.m. or above apparently gives best results.

2. Where the detention period following treatment exceeds 40 hours a second ammonia-chlorine application may be necessary where the water temperature is 70 degrees F. or above.

3. Certain types of algae develop a resistance to chloramine and chlorine treatment. These may be removed by the application of copper sulphate.

This effect has been observed at Kansas City, Kansas, by Mangun, who makes the following statement: "Organisms, particularly certain protococcus forms of algae, gradually develop a tolerance toward chlorine when it is continually present, in which state they become extremely sensitive to the algicidal action of small doses of copper sulphate."[7]

Such algae are apparently able to break down chloramine once this tolerance is developed, since residual chloramine is rapidly dissipated once the growths become established.

4. Chlorine treatment sufficiently great to partially oxidize organic matter may result in the putrefaction of sludge in reservoirs.

5. Powdered activated carbon may be successfully used in non-filtration plants for removing taste and odor producing substances, provided the water is properly coagulated and settled after the application of the carbon.

6. Powdered activated carbon may, when used in conjunction with chloramine, stabilize sludge in reservoirs.

7. Powdered activated carbon may prevent algal growths when a sufficient quantity is present to shut off light from reservoir walls.

8. Copper sulphate treatment when used alone, or following the application of chlorine, may result in putrefaction of sludge in reservoirs.

9. Proper control of tastes and odors in the treatment plant, together with proper bacterial control and clarification of the finished product, will materially lessen, if it does not eventually eliminate, "stagnation in dead ends."

(*Presented before the Missouri Valley Section meeting, November 8, 1934.*)

[7] L. B. Mangun, Chief Chemist, Water Department, Kansas City, Kansas, personal letter of September 7, 1934.

RELIEF PROGRAM IN BUFFALO

By Francis J. Downing

(*Executive Director, Emergency Relief Bureau, Buffalo, N. Y.*)

It will be my endeavor to lay before you the picture of the Emergency Relief bureau work relief program in Buffalo as it pertains to the water department of our city, both because our work relief program is considered a model of its type by state TERA officials and because it is felt you may find in our report suggestions for desirable work relief projects in your own communities.

On April 1, 1934, the Civil Works Administration which, through the Federal government had given jobs to thousands of Buffalo's unemployed, came to an end and Mayor Zimmerman appointed the present Emergency Relief bureau under the provisions of the Wick's act.

Under this Act and subject to the rules of the state administration, work relief and home relief, which had been handled separately during CWA days, were consolidated under one central administration. Under this consolidation we are confident the 28,000 or more families receiving relief in Buffalo at the present time are receiving far better treatment. And certainly the whole relief program, with all its constructive possibilities, is being conducted at a high level of efficiency.

What we are attempting to do in Buffalo is to preserve a man's pride as well as his possessions. At the same time we are planning to create for Buffalo equipment and improvements of high and lasting value coupled with exceedingly low maintenance costs.

High pressure water lines are being laid which will increase the city's protection against fire. Scores of sewer and street projects are being completed under the supervision of trained engineers and in coöperation with the regular city departments. Recreational facilities, swimming pools and playgrounds are being built by the work relief men for the benefit of the entire community.

All this work, paid for out of Federal, state and local funds, is being done by men who are paid in cash at the prevailing rate of wages in

the city. The cash payment approximates the sum they would receive if they were on home relief, but it allows them greater freedom in using it as they see fit.

It is our belief that a work relief system which does not produce worthwhile projects from the standpoint of the taxpayer, as well as from the standpoint of the worker, is a system not worthy of the name.

First of all we have been meticulous in our selection of projects in order to leave undisturbed the regular flow of business and industry apart from relief in our city.

Nothing is being done under our work relief program that could be done under the ordinary routine of budgetary allowances for at least another ten years or longer. And no work is being done by us that could be let to private industry by the city at this time or for many years to come.

REASON FOR WATER DEPARTMENT PROJECTS

Under such a program we naturally turned to the Buffalo water department for a considerable amount of our planned construction and in this department we found hearty coöperation and mutual helpfulness.

While Buffalo has a splendid water system, many repairs, alterations and improvements were needed which the administrators could not take care of under regular labor and construction budgets. That is, almost all of the work done for the water department under ERB would have required extraordinary employment of labor at some time and hence represented at the present time work that could be done with least disturbance to the year-in and year-out labor setup.

Furthermore, water department projects are ideal outlets for work relief, as these projects involve a high requirement for manual labor compared to material and equipment investment.

ERB requires of every project that it does not saddle the future with high maintenance charges, which would connote artificial construction merely to occupy labor. We want worthwhile constructive projects which cost little to run. Water projects fit in naturally, almost ideally with this program.

REVIEW OF WORK UNDERTAKEN

As we began to lay out this greatly enlarged work program for the water department it was found that the departmental draughtsmen

staff would be insufficient for the job and practically the first work assignment from ERB to the water department involved 28 draughtsmen who are now working in the water department office, taking care of ERB projects as well as helping with regular city work in bringing all plans up to date.

This launched the ERB water department program without disrupting the staff. Incidentally, these draughtsmen, as well as all other men used in these projects, are first qualified as in need of home relief before they are assigned to work relief jobs.

For a long time the North Main street section of Buffalo, following a period of rapid development, had been in need of water line extensions. Under ERB work relief 1404 feet of 36-inch pipe were hooked in from a Starin Avenue connection to act as a booster or primary feed line in that section, feeding a network of lines already installed.

The new line, which is designed for 85 pounds pressure, cost $58,991 of which $36,556 went for labor and $20,846 for materials.

Another major project, not yet completed entirely, involved extension of lines through South Buffalo. Here ERB workmen laid 1530 feet of 20-inch pipe and are finishing 7924 feet of 12-inch pipe. Total expenditures will be around $70,000.

The South Buffalo extension was a necessary secondary supporting feed line installed on the low service system throughout three thickly settled sections of the city. The extension will triple the water supply for the district in volume, will provide a constant pressure of approximately 32 pounds to the lines and will greatly increase available fire protection.

Installation of a sump line and bypass at the Col. Ward pumping station, main source of supply of the Buffalo system, was another ERB project that effected a needed and vital improvement. There had been no hope for this project under the regular city budget.

This line extends from the interior of the station to Black Rock harbor, about 500 feet, and will act in case of a break between pumps in the station and the main lines. The sump system will prevent a shutdown and flooding of the station proper during a break. The line has a 16-inch main laid below the frost line.

Out along the harbor turnpike on the city's southwest lakefront is a section of industrial and lake terminal property that is a vital part of future lakefront development. But along this area there is a gap of 3000 feet between dead ends of a 16-inch line that serves the district.

ERB workmen are hooking up this 3000-foot connection and have

engineered an 800-foot fill to carry the job and bring it to grade. The result is a very important secondary feet line long needed in the district.

Just recently ERB went into the reservoir cleaning business and so far our workmen have partially completed the job of draining, cleaning and repairing the Best Street reservoir with a capacity of 116,000,000 gallons. This reservoir, located on the highest elevation of the city, supplies the low pressure section of the Buffalo system, or approximately one-third of the entire setup.

Thus far ERB has expended $6075 on this project of which only $20.36 went for materials.

ERB DOES BIG ODD JOBS

Some very important odd jobs have been done for the city water department by ERB workmen. Here are some of them:

Our men are at this time painting 7415 hydrants throughout the city.

They are checking 17,500 curb boxes of the city system and will make repairs where there are leaks. Boxes that have sunk due to any reason will be restored to grade. A great saving in water loss will be effected.

More than 20,000 valves in the city system will be inspected and oiled. Stuffing boxes will be repacked. Recently two bad breaks occurred on the Fargo Avenue water line and it was discovered then that the valves would not function properly. The water department looks on this job as of vital importance since this discovery, yet it would have been unable to complete it without some extraordinary budget action.

ERB workers recently cleaned the sand filtration beds at the Col. Ward plant at a cost of $6075. The gravel depth of this installation is 16 inches and is made up of five graded layers. There is a 26-inch depth of filter sand of approximately 0.38 to 0.45 mm. effective size.

HIGH PRESSURE FIRE LINE

One of the largest single projects being carried out in coöperation with the city water department is the installation by ERB workmen of a high-pressure water line from the Col. Ward station throughout the downtown business and industrial sections for fire fighting purposes.

Approximately 10 miles of high pressure pipe will be laid under this

project which will serve 220 new hydrants throughout the congested area of the city. A normal pressure of 78 pounds will be maintained when the system is idle, but new pumps at the station will jump the pressure to 300 pounds when an alarm sounds in the area served.

The line will serve the main business and mercantile districts and branch off through rich industrial warehouse areas along the southwest section of the city.

The project, with all supplements to date, is estimated to cost $1,777,363. The labor charge is $862,348 and expenditures for materials total about $915,000.

From ERB's point of view this is a particularly fine work relief project, inasmuch as almost all the work is being done by manual labor, due to the heavy underground congestion throughout the downtown district.

As an example of the constructive nature of ERB projects the installation is striking. It was asked 13 years ago by the Board of Fire Underwriters as an essential fire protection move for the prevention not only of unit fires, but to insure against widespread conflagrations. But during all this time city departments, for one reason or another, were unable to do anything towards launching of the project. It was an excellent and natural outlet for ERB work relief and is now thoroughly appreciated by the downtown taxpayers.

It is interesting to note that the new fire line will serve a dual purpose in that it will make available much of the present downtown fire fighting apparatus for use in outlying residential districts. Mobile fire department pumpers have a capacity pressure of about 100 pounds. Naturally they will be unnecessary on the new high pressure line.

ERB HELPS HOSPITAL

Another instance in which ERB resources permitted direct action in an emergency is shown in the project to create a permanent water supply for the J. N. Adam Memorial hospital at Perrysburg, about 32 miles south of Buffalo.

This institution, located on the crest of a slope 1600 feet above sea level is at the peak of the watershed between the St. Lawrence and Mississippi valleys in this section. The water runoff to the north flows in the St. Lawrence, while the southerly runoff finds its way into the Gulf of Mexico.

The hospital at the present time is supplied by a series of wells all

located close around the hospital on high ground and all near the point of exhaustion. It is conceded that the hospital may suddenly find its supply definitely cut off and, in fact, water conditions were exceedingly bad during the past summer, both as to quality and available supply. No funds have been available for enlarging this system.

ERB has stepped in, at request of city and hospital officials, has completed a thorough survey of the area and has originated a project which will effect a fundamental solution.

Our engineers have located a terminal moraine area underlying a wide district with a natural underground sink with a center about two and one-half miles west of the hospital. This moraine basin extends more than 20 miles and will insure a vast supply of the purest water.

ERB's test boring disclosed a water stratum of about 35 feet at the underground bottom of this moraine sink. Our project proposes a 180-foot well at a spot 1310 feet above sea level.

Our initial boring struck an artesian flow of 15 gallons per minute through a 6-inch pipe.

We propose to sink a 28-inch hole under the Clay Seal process with a 24-inch drilling tube. A combination suction-blast and pebble injection system will be used to clear out the underground water cavern of sand and provide a filter area of considerable extent. Dry ice cubes will be forced into the drilling tube to generate gas pressure for giving a final force to the sand elimination process.

The pump proper will operate in a 16-inch inside diameter tube of stage lift design operating in a vertical shaft. At the top of the well, the water will run off into a pump house where electric pumps will feed it to the reservoir at the rate of 200 gallons per minute.

It requires a 1300 foot lift for the 354-foot change in elevation from the pump house to the reservoir, the latter being of 1,500,000 gallon capacity already in service with the old system.

The pumps will be entirely automatic, being actuated by a one-foot change in the reservoir level.

The total cost of the project will be approximately $87,000 of which approximately $32,000 will go to work relief.

What would happen if the water supply should become exhausted at this hospital can easily be imagined. We feel that ERB is making possible direct action in what virtually amounts to an emergency and that the job is typical of the ideals we have set up for our relief program.

ERB EMPLOYMENT RECORD

To sum up, the Emergency Relief bureau has employed an average of 1295 men per week on water department projects since creation of the bureau last April. The total per day, of course, has varied considerably, but the average since the ERB program started is set at this figure.

During this period the Emergency Relief bureau has expended a total of $517,700 for work relief labor on water department projects. This expenditure resulted in a total of 927,372 man hours of work for the unemployed of Buffalo and has given the city an incalculable creation of civic values.

When the ERB program in conjunction with the water department winds up, this city will possess one of the finest water systems in the world.

Altogether a total of $8,089,906 was expended for work relief in Buffalo under CWA and ERB administrations during the past year. This labor has been justly and fairly distributed throughout the city's unemployed and marks a new standard for relief administration.

We do not know how long our good projects will last, nor do we know how long adequate funds for materials and labor can be provided. But as long as the projects and funds are made available, Buffalo intends to offer to those of its unemployed who desire to work, a real opportunity to perform useful labor and to receive a relief payment in cash which, in the opinion of home relief authorities, will provide the necessities of life for them and their families.

All of us realize that this cannot possibly be a substitute for normal industrial employment, but we do believe that our present work relief system is the best that has been devised anywhere in the state. Many states in the country have based their unemployment relief programs on New York laws, rules and practices. Buffalo hopes that by building a system which we consider practical as well as humane we will be able to contribute to the general solution of the nationwide relief problem.

(*Presented before the New York Section meeting, October 11, 1934.*)

GROUND-WATER PROBLEMS OF THE COASTAL PLAIN

By O. E. Meinzer

(Geologist in Charge, Division of Ground Water, United States Geological Survey, Washington, D. C.)

The broad lowland belt that extends along the Atlantic and Gulf coasts from New York to the Rio Grande is underlain by sedimentary strata ranging in age from Cretaceous to Recent. These strata consist chiefly of alternating beds of sand or gravel and clay, but also include much limestone and also other kinds of rock. They are largely of marine origin, showing that during much of the time since the early Cretaceous the Coastal Plain has been at least partly below sea level. As a rule the beds dip gently toward the sea, and successively younger formations appear as one approaches the sea. Many of the sand and gravel beds and some of the limestones contain large quantities of water which they yield freely. The clayey beds function as confining beds. Thus, as a rule, the water-bearing beds are replenished by rain and snow at their outcrops; thence, the water percolates down the dip, and on the lower lands, nearer the sea, it is under sufficient artesian pressure to rise to the surface when wells are drilled into the water-bearing formations.

Throughout the Coastal Plain ground water, recovered from pumped or flowing wells, is extensively utilized for domestic and industrial supplies; most of the public water supplies are obtained from wells, including a large majority of the smaller municipalities and some of the large cities, such as San Antonio, Houston, Memphis, Jacksonville, Savannah, and Camden; and west of the Mississippi, large supplies for the irrigation of rice and other crops are obtained from wells. For example, during the irrigation season, the daily pumpage from wells in the Grand Prairie rice district, in Arkansas, is about equal to the daily water consumption of the entire city of New York.

The major ground-water problems of the Coastal Plain relate to both the quantity and the quality of the water. Where such large supplies are being drawn from wells each year as in the Grand Prairie district, it is obviously important to obtain reliable information as

to the safe yield; that is, as to how much of the water is being drawn from storage and how much is provided by the annual replenishment. The underground storage, even though it may be very large, is not inexhaustible. Ground-water developments should be planned on the basis of the average annual replenishment, the storage capacity of the water-bearing formations providing for full utilization of the supply as needed. A large part of the work of the Ground Water Division of the United States Geological Survey relates to the problems of safe yield. Increasing attention is also being given to the possibilities of artificial replenishment with surface water that will otherwise run to waste.

Many of the formations that underlie the Coastal Plain contain water that is too salty for use. Some of the formations contain fresh water near their outcrops but salty water where they pass to greater depths nearer the sea. In large parts of the Coastal Plain, however, fresh-water formations occur below formations that contain salty water. The problems of the occurrence of fresh and salty water and their interrelation are very complex. The salty water appears to be in part entrapped ancient sea water, but in many places there appears to be at present a balance between the fresh water and the heavier sea water. Whether in a given formation there is a perennial seaward movement of fresh water or a stagnant clogging of the formation with sea water depends on several conditions, such as the head of the fresh water as determined by the altitude of the outcrop that forms the intake area; the permeability of the confining beds, which may permit upward percolation of the fresh water with consequent loss of head; and the depth of the submarine outcrops, which determines the counter-pressure of the heavier sea water. In the investigation of this subject, a contour map showing the artesian head in all parts of the Florida peninsula has recently been made by V. T. Stringfield and F. C. Westendick.

As soon as water is withdrawn from wells by pumping or artesian flow, the pressure is reduced in the vicinity of the wells, and the drawdown may disturb the balance between fresh and salty water and may induce flow of salty water toward the wells—either laterally through water-bearing beds or across the stratification, from one water-bearing bed to another, as seems to occur, for example, at New Bern, N. C. However, fresh-water wells often become salty by local contamination that can be remedied. Thus, in a well that passes through a bed of salty water into a bed of fresh water, the casing may

become corroded where it passes through the salt-water bed, with the result that salty water enters the well and may even contaminate the fresh water for some distance around the well and appear in the water pumped from other wells in the vicinity.

The deep-well current meter, salinity apparatus, and water samplers that have been developed by the United States Geological Survey are proving valuable in investigations of this kind.[1] The current meter records the upward velocity of the water in a well at all desired depths. Therefore, if the diameter of the well is known it gives the rate of upward flow at each level and hence the levels at which water enters the well or is lost through leaky casing. The salinity apparatus measures the electric conductivity of the water and hence its approximate content of dissolved mineral matter at all desired depths. More accurate data as to the mineral content of the water at different levels can be obtained by laboratory analyses of water obtained by means of the deep-well samplers. With information thus obtained it is generally possible to locate the source of contamination, and if the well draws from more than one water-bearing bed, to select the source that yields the best water.

During a large part of late geologic time, after the principal formations had been deposited, the sea stood higher than at present, and much of the surface became mantled with alluvial or littoral deposits of sand and gravel. These surficial deposits are largely water-bearing and supply many of the shallow domestic wells. On parts of the Coastal Plain where the deeper water is highly mineralized, this shallow ground water has a value for municipal and industrial uses that has not been fully appreciated. The recovery and use of this water involves a number of special problems, which have received some study but deserve much more.

About 1931 it was found by G. I. Stewart,[2] Director of the Michigan Forest Fire Experiment Station, that in large areas underlain by glacial outwash sand and gravel, wells which yield enough water to

[1] Meinzer, O. E. Methods of exploring and repairing leaky artesian wells: Preface, pp. 1–3; McCombs, John, Methods of exploring and repairing leaky artesian wells on the island of Oahu, Hawaii; pp. 4–24; Fiedler, A. G. The Au deep-well current meter and its use in the Roswell artesian basin, New Mexico: U. S. Geol. Survey Water-Supply Paper 596a, 1928.

Fiedler, A. G. Deep-well salinity exploration: Amer. Geophysical Union Trans., pp. 478–481, 1933.

[2] The Michigan Forest Fire Experiment Station—what it is and what it is doing: Michigan Dept. of Conservation, 1932.

supply a fire hose can be washed down and put into service in only a few minutes. Since that time the Michigan Geological Survey, with the coöperation of the United States Geological Survey, has made a survey of the water-bearing sand and gravel in about 100 townships, and by the aid of C. C. C. labor has put down about 2,000 wells to test the water-bearing properties of these deposits in different localities. The successful results in Michigan led the United States Geological Survey to undertake a preliminary investigation of the possibilities of developing water supplies from the shallow deposits of sand and gravel on the Coastal Plain. A small jetting rig was purchased for the purpose and has been in operation for several months. Most of the test well work thus far has been done in New Jersey, but at present work is in progress in Robeson County, N. C. Many laboratory tests of the permeability and other physical properties of the water-bearing materials are made to correlate with the rather exact field data that is obtained as to the yield and drawdown of the wells. The results, which are favorable in some localities and unfavorable in others, will later be presented in detail. The objectives of the investigation relate to use of the water for municipal and industrial as well as fire-control purposes. The investigation is in charge of A. G. Fiedler, with W. H. Monroe as geologist and M. A. Pentz in charge of the drilling work.

Another opportunity to study the surficial water-bearing deposits was afforded by the ground-water investigation that has recently been made in the vicinity of Elizabeth City. This investigation was made by S. W. Lohman of the United States Geological Survey, in coöperation with the North Carolina Department of Conservation and Development and the authorities of Elizabeth City, and has led to the development of the new water supply for this city. The test drilling indicated that water of better quality could be obtained from the surficial deposits than from any of the deeper strata, and led to a rather intensive study of these deposits within practicable distance from the city. It was necessary to find a location for the well field where the water table is considerably above sea level so that the drawdown produced by pumping will not bring up salty water from greater depths. It was also necessary to find a location where the water-bearing sand is sufficiently thick and permeable to afford reasonably good yields to the wells and to store enough water to last through the periods of drought. Moreover, it was necessary to find a location where the water is as soft and free from dissolved iron as

possible. The site chosen seemed best to meet all these requirements. Even in this locality, however, the distance from the water table to the bottom of the water-bearing deposit is not great enough to allow very much storage of water, or to make it possible to develop a deep enough cone of depression to draw much ground water into the well field from the surrounding territory. The data show clearly that the supply must be obtained essentially from local replenishment and must be recovered through a considerable number of widely distributed wells.

The water in the surficial deposits is readily contaminated with bacterial pollution, and doubtless the water from a large part of the shallow domestic wells would show the presence of *B. coli*. However, it is generally practicable to safeguard the supply for municipal waterworks by locating the well fields where they can be protected from pollution, and, if necessary, by chlorinating the water.

Several years ago an intensive study of bacterial pollution of ground water was made at Fort Caswell, N. C., under the direction of Prof. C. W. Stiles,[3] of the United States Public Health Service, with the coöperation of the United States Geological Survey. In this investigation the ground water of the uninhabited experimental area was first found to be normally negative for *B. coli* by the examination, according to rigid technique, of more than 6,000 samples of water taken systematically over a period of several months. Certain wells and trenches were then dosed with the green coloring matter called uranin and with excreta abounding in *B. coli*. The course of the ground water through the sand underlying the area was traced by means of the uranin in thousands of samples recovered from hundreds of aseptic wells put down in the path of the slowly moving ground water, and the extent to which the *B. coli* moved with the water was determined by bacterial examination of the same samples. The water-bearing sand was shown by laboratory examination[4] to be a sand of fine to medium coarseness with an effective size of 0.14 millimeter, a uniformity coefficient of 1.9, a porosity of nearly 50 percent,

[3] Stiles, C. W., Crohurst, H. R., and Thomson, G. E. Experimental bacterial and chemical pollution of wells via ground water, and the factors involved: Report on the geology and ground water hydrology of the experimental area of the United States Public Health Service at Fort Caswell, N. C., by Norah D. Stearns: United States Public Health Service, Hygienic Laboratory Bull. No. 147, 1927.

[4] Op cit., Also Water-Supply Paper 596, pp. 152–159.

and a permeability coefficient of about 400. In one of the several tests (No. 600B) it was found that by the end of 7½ months the water had moved 115 feet and *B. coli* was found throughout 65 feet of this distance and was still alive. In the same test it was found that by the end of two years and seven months the water had moved a total of 450 feet and *B. coli* was found as far as 232 feet from the source and was still alive.

In 1931 a program of systematic observations of the ground-water levels was begun in North Carolina, through the efforts of Thorndike Saville, at that time Chief Engineer of the Department of Conservation and Development, and E. D. Burchard, District Engineer, United States Geological Survey. A number of unused wells that do not extend far below the ground-water table were selected in different parts of the State. Some of the wells were equipped with automatic water-stage recorders and in others the depth to the water surface has been measured at frequent intervals. Programs of this kind are now being developed in many other States and are being shaped into a comprehensive nation-wide program. If this program is maintained it will be possible at any time in the future to determine the stage of the ground-water table and the extent of replenishment or depletion of the ground-water supplies.

(Presented before the North Carolina Section meeting, November 13, 1934.)

WATER WASTE SURVEYS AND DISTRIBUTION SYSTEMS STUDIES

By D. D. Gross

(Chief Engineer, Board of Water Commissioners, Denver, Col.)

Leaky water mains and all the other forms of water waste demand a great deal of the water superintendents' time and thought. A great deal has been written in waterworks literature about water waste. These problems and their solutions are growing in importance. No longer is it sufficient to repair those leaks that present themselves to the attention of the superintendent, but it is found profitable to make systematic search for leaks and all other forms of waste. Leak surveys are not new but in recent years have increased in popularity.

In making waste surveys other useful information concerning the distribution system may be learned. The carrying capacity of the pipe system as affected by tuberculation and the desirability of cleaning the mains can be learned and answers to the following questions obtained:

Do friction losses justify the cost of pipe cleaning?

Are the present feeder mains adequate, and are they doing what they are supposed to do?

Where should additional feeder mains be installed as water consumption increases?

What is the most economical method of reinforcing the pipe system?

Water waste may be classified under four heads:

1. Leaks from broken or pitted mains, valves and fire hydrants.
2. Leaks in service pipes between the city mains and the meter or fixtures.
3. Leaks from fixtures and waste flow through fixtures including garden hose.
4. Under registration of meters (a financial rather than a physical leak).

There are many ways of locating and stopping waste. The best way to remedy Class 3 waste mentioned above, namely—waste

through fixtures, as by the installation of meters. But even meters may permit waste if not of the correct size for the service performed, and if they are not regularly examined and tested. Furthermore, meter rates may foster waste.

Mr. John Chambers, Chief Engineer and Superintendent, Louisville Water Company, makes a report indicating that in Louisville, Kentucky, the meter rates should be revised in the interest of waste reduction. When meters were first installed there was a material reduction in the use of water, but after they had been in use three years there was a notable increase due to the fact that householders had discovered that they could use more water than they had been using without overrunning their minimum bill.

If a city is not metered, frequent inspections are required if waste is to be kept within reasonable limits. The rate of flow during the minimum night hours may be expected to be upwards of 50 percent of the average daily consumption, even though frequent inspections are made. Householders, as a rule, resent frequent inspections of plumbing. In case of extreme water shortage intensive publicity campaigns are very effective in curbing waste through fixtures during the emergency.

Usually the largest percentage of waste is through the fixtures and it would seem to be inconsistent for a city to incur large expense on waste survey before installing meters on all or a large percent of the services.

New York City, with about 26 percent of the services metered, detected leaks in mains and service pipes by means of aquaphone surveys at an estimated cost of $2.42 per million gallons of water saved.

The city of Chicago, after many years work on leak surveys, estimated that the underground street leakage in the distributing mains, including service pipes up to the stopcock at the curb, was approximately 8.8 percent of the average daily pumpage; the total pumpage for the year 1932 being 1,010,000,000 gallons per day, and the estimated leakage 88,730,000 gallons per day. The surveys did not cover the entire city, nor did they detect all the leaks in districts investigated after these years of effort.

The per capita consumption of Chicago for the year 1932 was 285 gallons, which would indicate that the leakage and waste through fixtures was many times the leakage through street mains, perhaps greater than the legitimate use.

Waste, listed under Items 1 and 2 above, namely, leakage from

water mains and service pipes, and loss under Item 4, are usually investigated at the same time in making surveys, although in many cities the cost of repairs to service pipes are paid by the consumer.

Doubtless water works men have been hunting for leaks since the days of the Romans, but systematic surveys seem to date from 1873, when Mr. George F. Deacon began such surveys in Liverpool, England. Very definite progress was made in methods of waterworks surveys in 1895 when Mr. Edward S. Cole developed the "Pitometer" based on Pitot tube principal. This pitometer has become a standard instrument for use in making waterworks surveys.

Other methods and other instruments have practical or special use. In fact, other instruments are quite essential in making a pitometer survey other than the pitometer itself. These instruments include the aquaphone, sonoscope, geophone, Darley leak locator, and many other similar instruments sold under different trade names. While intended primarily for other purposes, the pipe detector and wireless pipe locator are sometimes useful.

The aquaphone and similar instruments are used to amplify the noise made by water escaping from pipes. The aquaphone is an instrument similar to a telephone receiver with the magnets removed. A metal rod passes through the instrument and is attached to the middle of the diaphragm.

In Denver we have been using an instrument constructed from an ordinary telephone receiver. The screws at the lower end of the magnet for attaching the wires are removed. A hole is drilled in the end of the magnet in which a brass stud is installed. When the equipment is assembled this brass stud protrudes from the small end of the receiver through the hole originally provided for the wires.

In using the aquaphone the operator places the metal rod or stud against the pipe, valve or fire hydrant being investigated, and holds his ear to the phone and listens for the noise of water escaping at some adjacent point on the pipe system. The instrument may be held against an iron rod driven into the ground, so as to touch the water pipe, or it may be held against a valve key. By listening at different points on the system for the volume of noise caused by escaping water, information as to the location of the leak is obtained.

Frequently when closing a valve, the operator places his ear to the valve key and listens for the noise of running water to determine whether the valve is closed. By using the aquaphone for this purpose he usually can obtain accurate information as to conditions.

The geophone is an instrument based on seismograph principles.

The instrument was originally designed for use in warfare, being used in tunnel and mining operations to enable officers to determine the presence and location of the enemy's forces engaged in similar work.

The instrument is used in duplicate, one for each ear. In appearance it is a thick disc in which a lead weight is suspended between two diaphragms formed in an air-tight box. Any vibration causes a disturbance of the air in the box and this disturbance is transmitted to the ear pieces resembling a stethescope.

In use it is not the intention to place the instrument against a water pipe in which it is desired to locate a leak, but to place it on the pavement under which a leaky pipe is located, and by moving the instrument about from place to place to find by trial the location of the leak. The observer places the instrument on the pavement with the two geophones about 3 feet apart. The noise will usually sound louder in one of the geophones; the other geophone is then moved in a circle around the loud sounding instrument to some position where the sound coming from both instruments is equally loud. If the observer then stands so that an instrument is on either side he knows that the leak is either in front or behind him, and by moving backward and forward he finds the spot where the noise is loudest.

Recently, in Denver, a service pipe located under a concrete floor in a garage, was known to be leaking. After drilling several holes in the floor, the garage owner appealed to the Water Department for help. A Water Department employee responded with a geophone. After moving the geophone over the floor for about fifteen minutes he spotted what he believed to be the location of the leak. The garage owner was quite certain that he was wrong, but finally decided to take his advice and found the leak at the place indicated.

The Pitometer Company, together with other companies and individuals, specialize in water waste surveys and are prepared to do this work either under contract or on a per diem basis. The popular method is one made on a contract basis in which the water department or water company furnishes labor and material and the Pitometer Company furnishes the instruments and necessary engineering supervision.

In proceeding with the special work of the survey the city pipe system is divided into convenient districts which are determined largely by the location of the main feeders in the city pipe layout. The district having been outlined, the valves on the boundaries are

closed, permitting a flow of water into the district through only one or two main feeder lines. The measurement of this flow of water is recorded on a pitometer chart making it possible to determine the amount of water used for any desired period of time; the records are continued for twenty-four hours or longer. Having determined the flow during minimum time of consumption, which is usually the small hours of the morning, further investigations are made through the district. By opening and closing valves within the district, smaller sections, even to single blocks of pipe, are investigated and any existing use, or rather waste, is traced in this manner. Frequently a survey of this kind reveals that the major portion of the waste is not in the city mains proper, but in service connections.

There seems to be a wide variation in the experience and results obtained in a survey of this kind in different cities. In Louisville, Kentucky, L. S. Vance, Assistant Engineer, informed me that the pitometer survey made in their city revealed two leaks in the city pipes proper. There were, however, a number of leaks, about fifteen, discovered in service connections and valuable information relating to the city pipe system was obtained as a result of the pitometer survey and made available for the use of the engineering department in planning for future extensions of mains, particularly the large feeder mains.

The Louisville Water Company installs both water mains and service pipes with their own forces, and attribute the small amount of leakage in their city pipe system to this method.

In Des Moines, Iowa, M. K. Tenny, Assistant to the General Manager, informed me that they were conducting an aquaphone waste survey, that two men, with the necessary men to follow up, had located and stopped many leaks and that in a year they had increased the accounted for water from about 72 to about 80 percent.

In Cincinnati, A. S. Hibbs, Superintendent, informed me that they were maintaining permanent gauging points controlling districts as originally outlined in the pitometer survey, and had set up a sum of $7,500 in their present year's budget for check survey, their plan being to go over the entire city once in every five year period.

It is interesting to note that Cincinnati is 100 percent metered and that the minimum night load ranges through the various districts at from 25 to 30 percent of the total consumption for twenty-four hours. This is used for a guide in interpreting the information obtained in the check gauging taken in the survey. If a district

night load falls within those limits, leak conditions are considered satisfactory from the standpoint of pitometer survey.

In many cities, especially those cities having the older water plants, the saving in the cost of producing the water, filter plant and pumping costs, made as a result of pitometer survey, has been very gratifying. In frequent cases this saving has been sufficient to more than pay for this survey in a single year. Frequently the survey has revealed the presence of water mains not known to exist. This information has proved important, especially when the water main proved to be a cross-connection between two main feeder lines. Surveys have also revealed closed valves and even cases of valves that were broken and closed, the existence of which was not known to waterworks officials. As stated above, probably the most prolific cause of waste with resulting benefits when discovered and eliminated has been in service pipes. In many of the large eastern cities there are many abandoned services. These are pipes originally installed to serve premises that have since been torn down and replaced with modern buildings, the old service pipes remaining in the street to give trouble. In spite of all care and precautions taken the service pipe is a less reliable part of the system than the water mains themselves.

Many of the larger cities, after having engaged the Pitometer Company to make the original surveys for them, and trained their employees in the use of the pitometer, have maintained a permanent survey of their own.

New York City has for years maintained very extensive waste surveys, using aquaphones for the major portion of the work with pitometer guide, Mr. Fred B. Nelson, who is an engineer on this work for the city of New York, for the boroughs of Manhattan and the Bronx, has discussed features of their work at several of the waterworks conventions, and gave a very detailed and splendid paper at the 1934 Convention in New York City. In these two boroughs they have for years maintained four parties responding to complaints of leaks. Because of the rocky formation in which the pipes are laid, water escaping from pipes makes considerable noise, and a great many leaks are reported to the department by annoyed householders.

A method frequently used in testing small sections of the distributing system is known as the meter and hose system. The water meter is loaded on a truck with a supply of fire hose. The water main in the district to be tested is valved off with the exception of one valve. A fire hydrant is opened, the last valve is closed. The

flow from the fire hydrant, of course, should stop with the closing of the last valve. If it does, proof is had that the valves are all tight. One fire hydrant within and one without the district are then connected to the meter by the fire hose. By this method all the water consumed within the district must pass through the fire hose and meter. This test is usually made at minimum hours of consumption at night, in an effort to discover what the leakage from the system is at a time when there is little or no consumption. Some times all service connections are closed in order to give a definite test for any leaks on the pipe system. This plan is also a good one to detect the illegal use of water, either through fire service connections or through unauthorized connections.

The adequacy of the city distributing system may also be tested by the use of pressure gauges and flow tests on fire hydrants Recording pressure gauges should be installed at selected points on the distributing system and permanent records kept of the pressure. These records should be supplemented by pressure tests made on fire hydrants at times of average and maximum consumption so that the superintendent will be informed as to the controlling pressures throughout the distributing system. Flow tests taken on fire hydrants making use of Pitot tube will give the valuable information to apprise the superintendent and engineers as to adequacy of the system, as to the desirability of reinforcing mains and extensions of feeder lines. The method frequently followed by engineers in investigating the distributing system is to prepare a map showing elevations of fire hydrants and pressures on all fire hydrants. The water elevations are obtained by adding the static head on fire hydrants in feet to the elevation of the ground at the fire hydrants. These water elevations are then platted on the map as contours, making it possible to readily locate areas of low pressures. This information, taken in conjunction with maximum flows from fire hydrants, gives useful information in regard to the distributing system's ability to meet maximum demands, and in preparing a design of the distributing system, the maximum demands must be considered and provided for.

Maps should be prepared showing the city distribution system and on these maps the proposed future extensions should be indicated.

Denver's water supply comes into the city by gravity and the major portion of the city is supplied by gravity pressure, but the higher portions of the city on either side of the Platte River are supplied from booster stations. We have carefully observed the amount of

water used in the districts supplied by these booster stations and have counted the services in order to gather information as to the demand of water per service.

TABLE 1

	CAPITOL HILL	ASHLAND	UNIVERSITY PARK
Number of services, 1931	13,402	8,700	3,916
Gallons pumped on maximum day	27,061,000	15,925,704	7,308,000
Gallons per service on maximum day	2,019	1,830	1,866
Maximum rate of pumping per service ($2\frac{1}{2}$ times average)	5,047	4,575	4,665
Maximum rate of pumping per service, gallons per minute	3.5	3.2	3.2

TABLE 2

Assuming standard 600 feet block solidly built with 1 house every 50 feet, that is, 24 houses to the 5 acre block, and taking average consumption of all stations, that is, 3.36 gallons per minute or 4,832 gallons per day demands would be:

BLOCK	ACRES	GALLONS PER MINUTE	GALLONS PER DAY
1	5	81	115,968
8	40	645	927,744
16	80	1,290	1,855,488
32	160	2,580	3,710,976
64	320	5,161	7,421,952
128	640	10,322	14,843,904

TABLE 3

Using 4 feet per second as maximum velocity in mains without excessive loss of head we get capacities and areas that can be served by given size mains as follows:

SIZE	CAPACITY	VELOCITY	ACRES THAT CAN BE SERVED	HOUSES THAT CAN BE SERVED	LOSS OF HEAD PER 1,000 FEET
inches	*m.g.d.*				
6	0.5	3.94	22	103	16.9
8	0.9	3.99	39	186	12.4
12	2.0	3.94	86	414	7.6
16	3.6	3.99	155	745	5.6
20	5.5	3.90	237	1,138	4.1
24	8.0	3.94	345	1,656	3.4
30	12.0	3.78	517	2,483	2.8
36	18.0	3.94	776	3,725	2.1
42	24.0	3.86	1,035	4,967	1.7

As an aid in designing extension of mains in the residential districts, we have tabulated this information which reveals that the maximum rate of pumpage per service ranges from 3 to 3.5 gallons per minute. On this basis we have computed the amount of water required to supply different units of area from 5 to 650 acres. From this table we have computed the size of pipe required to deliver the water under the average pressure conditions as they exist in Denver, that is, to determine the size of pipe that will deliver the quantity of water required to supply a given area fully built up at a satisfactory pressure. We find that under our conditions a velocity in the pipe of about 4 feet per second, ranging through the different sizes of pipe, is about the maximum which we can design for and keep pressure losses within our required limits.

All of this information is presented in tables 1, 2 and 3.

The sizes of main feeder piping are materially reduced by the proper location of storage reservoirs or elevated storage tanks to relieve the conduit system during hours of peak consumption.

Mr. Charles B. Burdick, of Alvord, Burdick & Howson, estimates that the excessive peak consumption rate in Denver can be reduced 59 percent with respect to the load placed on the distributing conduits and pumping stations by providing properly located storage capacity of 85 gallons per capita; that is, whereas table 3 would indicate a 42-inch main to supply a population of 25,000 (4967 services), if proper storage is provided this population could be supplied by a 30-inch main.

(*Presented before the Rocky Mountain Section meeting, September 11, 1934.*)

COLOR AND ODOR REMOVAL AT OSSINING, NEW YORK

By Wallace T. Miller

(*Superintendent, Board of Water Commissioners, Ossining, N. Y.*)

and

James E. Kerslake

(*Supervising Chemist, with Nicholas S. Hill, Jr., Consulting Engineer, New York City, N. Y.*)

The Village of Ossining, Westchester County, New York, placed in operation a new filtration and pumping plant on April 13, 1931. In the three years that the plant has been operated, a number of problems have been encountered and some interesting data have been collected, particularly on the removal of color and odor.

Ossining is located on the Hudson River, about thirty miles north of New York City. The population is 15,200, of which 13,400 are served by the municipally owned water system. The average daily pumpage is approximately 800,000 gallons, the per capita consumption being about 60 gallons per day.

SOURCE OF SUPPLY

The supply is taken from Indian Brook Reservoir which is located on a small tributary of the Croton River about two and one-half miles north of the center of the village. The reservoir has a storage capacity of 94 million gallons and a drainage area of 1.33 square miles.

Before the new plant was built water flowed by gravity from the reservoir through a 16-inch supply line for one-half mile to the pumping station, where it was chlorinated and pumped to the distribution system by means of motor driven centrifugal pumps. This station was abandoned and the pumps moved to the filter plant when the latter was constructed. When the supply ran low, water could be taken from the Old Croton Aqueduct by gravity as the supply line from the reservoir crossed the aqueduct on its way to the pumping station. In order to obtain water from the aqueduct under the new arrangement it was necessary to install a tank and vacuum pump in the filter house to prime the pumps in their new location.

THE FILTRATION PLANT

The filtration, aeration and pumping plant has a capacity of 2 million gallons per day. It consists of a raw water settling basin with aerator, a mixing tank, a coagulating basin, a combined filtered water and wash water basin with aerator, a filter house containing 4 rapid sand filters, 4 chemical dry feed machines, chlorination equipment for chlorinating the raw and filtered water, 2 motor driven low lift pumps and 2 motor driven high lift pumps.

Special features in the design and construction of the plant were:

1. Conservation of seepage through the Indian Brook dam by locating the plant so that the concrete walls of the coagulating basin and the substructure of the filter building intercept and impound it, the pool thus formed being utilized as a raw water settling basin.
2. Location of the filtered water basin on a side hill at an elevation suitable for washing the filters.
3. Removal of the old pumping equipment to the new plant.
4. Installation of a vacuum pump and tank in the filter house to keep the pumps primed when it is necessary to take water from Croton Aqueduct.

The water leaving the reservoir passes through spray nozzles into the raw water settling basin. From this basin it flows into the mixing tank, after being dosed with chlorine, carbon and alum. Thence it flows in a concrete conduit along one side of the coagulating basin, which it enters at the end farthest from the filter house. After passing through the coagulation basin and the four filters in the filter house it enters the suction well of the low lift pumps underneath the pipe gallery. There ammonium sulphate and lime are added. The low lift pumps raise the water from the suction well to aerators on top of the elevated clear water basin, the water entering the clear well after this second aeration. Next it flows by gravity to the high lift pumps in the filter house, receiving on the way a second dose of chlorine.

CHARACTER OF THE RAW AND FILTERED WATER

The raw water as it is drawn from the reservoir is clear and has a fairly high color and the characteristic vegetable and swampy odor of water collected from a watershed containing swampy areas. It is soft, that near the surface having a low iron content and but a trace of manganese, while the bottom water contains small amounts of iron and manganese. Since the plant was started, the maximum color has been 98, the minimum 29, and the average 55. The bacterial load on the plant is light,—the twenty-four hour count on agar

TABLE 1

Result of chemical and bacteriological analyses of samples collected at the Indian Brook Filter Plant and on the distribution system

CONSTITUENTS	RAW WATER LINE FROM RESERVOIR DRAWING FROM		SETTLED WATER TOP OF FILTERS	EFFLUENT TAP LABORATORY	TAP VILLAGE HALL
	Surface	Bottom			
Turbidity	None	1	—	None	None
Color	62	64	12	7	9
Odor	Faint vegetable	Faint swampy	None	None	None
Total hardness	40	38	42	62	62
Carbonate hardness (alkalinity)	21	22	11	36	36
Iron	0.12	0.8	Trace	Trace	0.05
Manganese	Trace	0.35	None (0.18)*	None (0.13)*	None
Carbon dioxide, free	4.8	13.2	17.6	None	None
Chlorine as chlorides	4.1	4.0	5.2	5.3	5.4
Chlorine, free	None	None	Trace	0.3	0.3
Dissolved oxygen	5.1	3.9	5.6	5.7	5.4
Consumed oxygen	4.1	5.2	1.9	1.0	0.9
Hydrogen ion concentration (pH)	6.9	6.5	6.0	8.7	8.5
Number of bacteria, agar 37°C., 24 hours	14	18	12	1	2
B. coli Present in	30 cc.	30 cc.	—*	—	—
B. coli Absent in	—	—	30 cc.	30 cc.	30 cc.

* When using water from bottom of reservoir.

at 37°C. never exceeding 100, and the average being 26. B. Coli were present in 39 percent of the ten cubic centimeter tubes shown. The effluent is clear, low in color and free from odor. It is soft, contains but a trace of iron and is free from manganese except when bottom water is used. The effluent is sterile. Water of the same quality as produced at the plant is found in the distribution system.

TABLE 2

Result of analyses of raw and filtered water

CONSTITUENTS	RAW WATER LINE FROM RESERVOIR (DRAWING FROM SURFACE)	FILTERED WATER EFFLUENT TAP LABORATORY
Turbidity	None	None
Color	62	7
Odor	Faint vegetable	None
Nitrogen as albuminoid ammonia	0.78	0.042
Nitrogen as free ammonia	0.008	0.006
Nitrogen as nitrites	Trace	0.001
Nitrogen as nitrates	Trace	None
Total solids	87	119
Organic and volatile matter	34	27
Mineral matter	53	92
Iron	0.12	Trace
Manganese	Trace	None
Total hardness	40	62
Carbonate hardness (alkalinity)	21	36
Sulfate, nitrate and chloride hardness	19	26
Chlorine as chloride	4.1	5.3
Chlorine, free	None	0.3
Carbon dioxide, free	4.8	None
Oxygen dissolved	5.1	5.7
Oxygen consumed	4.1	1.0
Hydrogen ion concentration (pH)	6.9	8.7
Number of bacteria, agar 37°C., 24 hours	14	1
B. coli: Present in	30 cc.	—
B. coli: Absent in	—	30 cc.

Results of chemical and bacteriological analyses of samples collected at the plant and from the distribution system are shown in table 1, and a more complete analysis of the raw and filtered water in table 2.

MANGANESE

During the past summer at the time of the hot weather experienced in July, it was found that the water at the bottom of the reservoir

was from 15 to 20 degrees Fahrenheit cooler than the surface water. In order to supply the consumers with a cooler, and, therefore, more palatable water the raw water was taken from the bottom of the reservoir. The bottom water was found to contain 0.35 p.p.m. manganese. This was reduced to 0.13 p.p.m. by the normal routine treatment. None was found at the Village Hall tap. The residual manganese was probably precipitated out in the distribution system by the lime treatment after filtration before it reached the sampling point. Experiments conducted at the plant indicated that the manganese could be reduced to 0.05 p.p.m. or less by increasing the prechlorine dose, about 100 pounds per million gallons being required. By the time the experiments were concluded the level of the water had fallen so that the difference in temperature between the surface and bottom water was less than 10 degrees Fahrenheit, and surface water containing but a trace of manganese was again used. Due to the presence of manganese, a correction of 0.15 p.p.m. had to be subtracted from the orthotolidine determination when testing the chlorinated raw water and 0.04 p.p.m. when testing the chlorinated filtered water.

GOLD FISH

In order to determine the effect of the higher and more prolonged residual chlorine content of the effluent due to the lime and ammonia-chlorine treatment, two gold fish were purchased and placed in a bowl in the plant laboratory. The water in the bowl is changed daily. It is drawn directly from the laboratory tap and allowed to stand two hours in order to reach room temperature before it is placed in the bowl. The fish appear to thrive. The residual chlorine content normally is 0.3 and has gone as high as 0.4 p.p.m.

RED WATER

The addition of sufficient lime to the filtered water to maintain a pH of 8.5 eliminated all complaints of red water, except at dead ends. These complaints were practically eliminated by the introduction of the ammonia treatment about two years after the plant was put in operation. Even at dead ends the color seldom exceeds 15, the iron content is less than 0.3, and there is a trace of residual chlorine. It was found necessary at first to maintain the hydrogen ion concentration at the plant between 8.8 and 9.2 to get one of 8.5 in the distribution system. Once this point was obtained, however, the concentra-

tion at the plant was reduced to 8.5; when the temperature drops to 50 degrees Fahrenheit it is reduced to 8.0.

FILTER OPERATION

A wash water rate of from 24 to 32 inches rise per minute is used, the rate being varied according to the temperature of the water. The filter runs vary from 24 to 40 hours, averaging about 30. The filters are washed when the loss of head reaches 7½ feet. The sand bed in the filters is level and free from cracks and contains a few small mud balls. The filters are given a chlorine treatment, using H. T. H., every spring and autumn and, if necessary, are scraped.

COAGULATION BASIN

The coagulation basin is flushed once each month through floor drains provided for that purpose. Twice each year in the spring and autumn it is completely emptied and thoroughly cleaned.

COPPER SULPHATE TREATMENT

The reservoir is treated with copper sulphate as soon as the ice breaks up in the spring, the dose being 2 pounds per million gallons. It is treated once a month thereafter with 1 pound per million gallons, except during July and August when it is treated twice a month with the 1 pound dose. A 2 pound dose is used in November just before the reservoir freezes over.

COLOR AND ODOR REMOVAL

When the plant was first started it was felt that with double aeration and pre- and post-chlorination, the occasional use of activated carbon would be all that was required to produce a satisfactory effluent. This did not prove true, and it was shortly decided to use carbon continuously. From 20 to 25 pounds per million gallons were added along with the alum. It was then found that approximately 40 pounds less per million gallons of alum were required to maintain a color of between 5 and 10 p.p.m. in the effluent.

Satisfactory results were obtained until August, 1933 when heavy rains raised the level of the three-quarter empty impounding reservoir about 10 feet. Odors developed. The carbon dose was raised to 45 pounds per million gallons. A better, but still unsatisfactory, effluent was obtained. Up to this time the pre-chlorine dose had been added before aeration with a very short contact period. The

pre-aerator was, therefore, taken out of service. Satisfactory water was then obtained for a short time. An odor characteristic of a chlorine treated swamp water was next observed in the plant effluent, although there was no odor in the filtered water after post-aeration before the final dose of chlorine was applied. Ammonium sulphate was then added prior to the final chlorine dose and an odor free effluent resulted. The ammonium sulphate dose was kept low at first and was gradually increased until a dose in pounds per million gallons equal to the final chlorine dose was reached (between 2 and 3 pounds). However, from 20 to 25 pounds of activated carbon per million gallons were still necessary.

In an attempt to cut the carbon dose, the point of prechlorination was changed from before to after the aerator, and the raw water aerator was put back in service. It was then found that the carbon dose could be cut from 25 to 15 pounds per million gallons. At times, satisfactory results have been obtained with as low as 10 pounds per million gallons.

OPERATING COSTS

A summary of the operating costs per million gallons filtered in the three years that the plant has been in operation is shown in table 3. Table 3 shows that the pumping cost is practically the same, the chlorine cost less, and the only extra cost involved other than for chemicals was for labor of one extra man and for part time supervision by a chemist from the office of the Consulting Engineer who designed the plant. The total operating cost, other than pumping, was approximately $12 per million gallons. The total cost, assuming a pumpage of 300 million gallons per year is $3,600, and the annual per capita cost 27 cents.

COST OF ODOR REMOVAL

The cost of odor removal per million gallons is given in table 4. It shows that a saving in chemical costs of 82 cents per million gallons is effected by pre-aeration, both the carbon and pre-chlorine dose being lowered. The aerator also smooths out the peaks in the odor load. A saving in alum cost of 64 cents per million gallons, due to the addition of the carbon, was also obtained. In addition to the removal of odors, the settled "floc" in the coagulation basin is stabilized by the carbon and there is less likelihood of obtaining a pin point "floc" during the winter months when the temperature of the water is low. Ammonium sulphate, in addition to preventing odors,

helps to eliminate red water trouble on the distribution system, and, due to the prolonged disinfecting action of the chloramines, it keeps

TABLE 3

Increase in operating expense resulting from installation of filter plant

	POUNDS	CENTS PER POUND	DOLLARS	
Chemicals:				
Alum	200	1.6	$3.20	
Lime	120	1.1	1.32	
Carbon	20	6.0	1.20	
Ammonium sulphate	2¾	7.0	0.19	
				$5.91
Labor and supervision:				
One additional man and supervising chemist				6.33
(Pumping approximately 300 M.G. per year)				$12.24
Savings:				
Chlorine—2 pounds at 5.5 cents			$0.11	
Pumping {Before $27.87*			0.49	
Pumping {After 27.38*				0.60
				$11.64
Net increase per million gallons			Say	$12.00
Total cost (pumping 300 million gallons) 300 × $12				$3,600.00
Per capita cost (population served 13,400)				$0.27

* Average power cost for three years—electricity at 2 cents per KW hour.

TABLE 4

Cost of odor removal per million gallons

ITEM	CENTS PER POUND	WITHOUT PRE-AERATION		WITH PRE-AERATION	
		Amount, pounds	Cost	Amount, pounds	Cost
Carbon	6	25	$1.50	15	$0.90
Chlorine	5½	11	0.60	7	0.38
Ammonium sulphate	7	2¾	0.19	2¾	0.19
			2.29		1.47
Saving in alum dose: 40 pounds at 1.6 cents per pound			0.64		0.64
Net cost			$1.65		0.83
Total annual cost, 83 cents × 300					249.00
Per capita cost					0.02

the water in the distribution system in better bacteriological condition, particularly at dead ends.

ACKNOWLEDGMENTS

The plant was built during the regime of Superintendent James Bedell, who retired in 1932 after 38 years service. Nicholas S. Hill, Jr., Consulting Engineer of New York City, designed and supervised the plant construction, and has since supervised its operation.

The authors are grateful for the aid given in preparing data for this paper by members of the Department, particularly Charles Merritt, Chief Engineer. The interest and coöperation of Mr. Barron, Sanitary Engineer, and his assistant, Mr. Taggart, of the Westchester County Health Department are also deeply appreciated.

(*Presented before the New York Section meeting, October, 1934.*)

THE TREND OF MODERN TASTE AND ODOR CONTROL

By F. E. Stuart

(Research Engineer, Water Purification Division, Industrial Chemical Sales Company, Inc., New York, N. Y.)

Tastes and odors are the subject of much conversation. Whenever a water supply develops an off taste or peculiar odor, immediate steps should be taken to improve the palatability of the water. This is not only important from a sense of duty to the consumer, but of unquestionable importance in keeping public relations satisfactory.

With the methods of control now at hand there is little excuse for characteristic tastes and odors, which in the past many cities have experienced.

The steps of most importance in eliminating these characteristic tastes are discussed below.

PRECHLORINATION

With the increasing use of prechlorination more water supplies are taking the load off filters and relieving the burden of final chlorination. This means chlorine residuals can be maintained in the post treatment with greater degrees of accuracy. Prechlorination therefore not only gives double assurance in sterilization control, but it renders more certain the elimination of a major taste problem, that of producing a sterile water with low chlorine residuals.

AMMONIA-CHLORINE

Soon after the advent of continuous prechlorination came the introduction of ammonia used in combination with chlorine. This treatment soon proved beneficial in eliminating chlorinous tastes produced by the necessary high dosages of chlorine in the post treatment. This was a decided step forward in taste and odor control.

Investigators began work on the power of sterilization of chloramines. They disagree on the results. One group claimed a "lag" in sterilization, another that no "lag" resulted. Other arguments regarding the importance of high and low pH values for immediate sterilization were brought up. With the use of prechlorination to

satisfy the demand of the water sufficient to produce a sterile effluent, ammonia-chlorine treatment could be used with complete safety, resulting in agreement of both groups.

Some found the application of ammonia-chlorine in the pretreatment to be the most beneficial. This is common practice in many plants.

Ammonia-chlorine treatment has proven itself to be an added safeguard for taste and odor control in almost every instance. It is primarily a taste and odor prevention process. The process prevents chlorinous tastes from developing when high dosages of chlorine are required or when the demand of the water is variable when accurate chlorine dosages cannot be maintained. Prechlorination and ammonia chlorine caused the public to become sensitive to variations in tastes and odors, that is, the two methods aided so much in the production of a more palatable water that whenever a taste did get beyond control, the consuming public noticed it and the new modern method, powdered activated carbon, was developed.

POWDERED ACTIVATED CARBON

Since the introduction of *Aqua Nuchar* (activated carbon) in 1930 considerable plant scale experience has been obtained. Much of this work has been done in Virginia through splendid coöperation by the State Department of Health under the direction of Mr. Richard H. Messer and in coöperation with the cities of Suffolk, Newport News, Norfolk and Richmond.

Careful observations were made at these plants and the results tabulated. Since the work in 1930 over 700 municipal water supplies use *Aqua Nuchar* in the conditioning of the water.

The early investigators on carbon treatment found that a suspension of carbon applied directly to the filters would improve the palatability of the water in a few hours, with an average dosage of 2 p.p.m. (16 pounds per million gallons) applied as a suspension from a barrel at a strength of 5 pounds carbon to 50 gallons of water. Shorter filter runs resulted in almost every instance. The removal of the taste producing compounds, however, offset the inconvenience of shorter filter runs.

Later investigators found that the *Aqua Nuchar* could be applied at the same dosage (2 p.p.m.) (16 pounds per million gallons) by dry feed machine equipped with water ejector to the mixing chamber. This method of application had the advantage of removing tastes

without shortening filter runs. It was found later, however, that it was advisable to apply carbon directly to the filters to "seed" them with carbon particles before beginning the treatment in the coagulation process.

About this time, an investigator in Florida found that carbon applied in the coagulation process would inhibit bacterial activity in the settled floc. This development is now known as "stabilization of sludge" and has become an important factor in securing maximum cleanliness in a filter plant.

Carbon will increase the efficiency of the coagulant by keeping the settled impurities in a sweet condition. In many instances carbon particles have aided coagulation, acting as nuclei for floc formation and possibly acting catalytically as carbon sometimes increased the efficiency of coagulation processes in turbid waters and in softening plants. An abstract of a recent questionnaire showing points of application of carbon and the percentage of plants in each instance using the method is shown below:

	percent
(a) On the filter	14
(b) In settling basin	19
(c) During the coagulation process	14
(d) Direct with the coagulant	53

This is quoted to show that many plants have found stabilization of sludge so important a factor that they use a small amount of carbon either separately or mixed with the alum continuously in order to keep the plant in a "sweet" condition.

To show dosages required for this work an abstract from the report of the committee on the Control of Tastes and Odors of the A. W. W. A., 1933, is given below.

DOSAGES APPLIED *pounds per million gallons*	PLANTS *percent*
1– 5	23
5– 10	30
11– 15	16
16– 20	12
21– 30	10
30– 90	6
91–110	3

In 81 percent of the plants reporting the use of carbon between 5 and 20 pounds per million gallons were sufficient for taste and odor control.

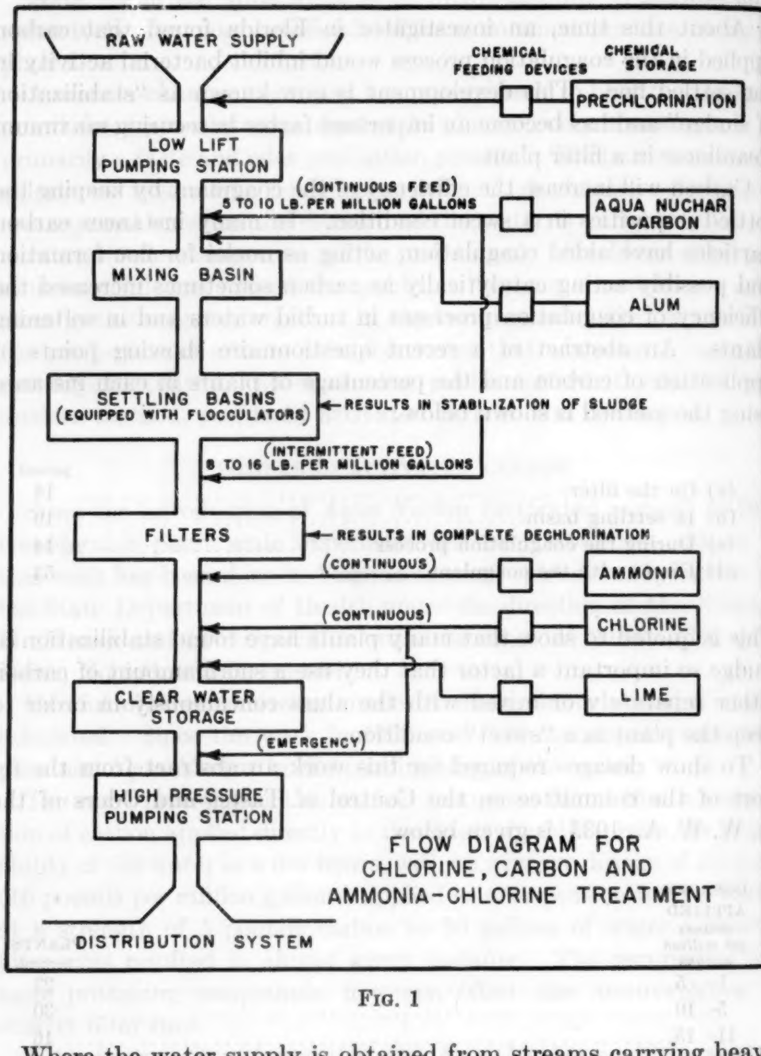

FIG. 1

Where the water supply is obtained from streams carrying heavy industrial trade waste polution, higher dosages of *Aqua Nuchar* are necessarily required, and should be used to insure complete taste and odor removal.

THE TREND OF MODERN TASTE AND ODOR CONTROL

The trend of modern taste and odor control is the use of prechlorination with carbon applied at dosages from 5 to 10 pounds per million in the coagulation process. Complete dechlorination is accomplished by the carbon particles in the floc deposited on the filters. Residuals can be maintained further through the basins when carbon is used because gases of decomposition are not present to react with the residual chlorine and remove it. After filtration, ammonia and chlorine are added in sufficient quantities to meet local conditions. The use of ammonia and chlorine after filtration in the water conditioned by prechlorination and carbon will in almost every instance keep down taste and odor complaints. Whenever the routine treatment of prechlorination and carbon in the coagulation process, with the resulting stabilization of sludge and dechlorination, allows a taste to develop that the ammonia chlorine process after filtration will not control, the addition of additional carbon directly to the filters will in almost every instance remove the taste. The average dosage of carbon is 2 p.p.m. (16 pounds per million gallons) applied directly to the filters as shown on figure 1.

ACTIVATED CARBON IN WASH WATER

The most recent development in taste and odor control originated in Norfolk, Virginia, where R. W. Fitzgerald is coöperating with the writer on the application of carbon particles to wash water. The dosage at this time is 0.5 p.p.m. (4 pounds per million gallons) applied to the filter when washing. The results will be published at a later date by R. W. Fitzgerald.

A duplicate experiment is under way at the Easton, Pa. plant of the Lehigh Water Company under the direction of R. W. Haywood. This method of taste control looks promising, as filters are running longer and apparently removing more taste producing organisms.

SUMMARY

The trend of modern taste and odor control is in the application of chlorine in the pretreatment; the addition of 5 to 10 pounds per million gallons of *Aqua Nuchar* to the mixing chamber which gives stabilization of sludge and subsequent dechlorination; the addition of ammonia and chlorine after filtration in sufficient quantities to meet local conditions. When tastes develop which the ammonia-

chlorine process after filtration will not control, additional *Aqua Nuchar* is applied as a suspension directly to the filter influent with average dosage of 2 p.p.m. (16 pounds per million gallons).

For future reference and experimentation the addition of carbon particles to wash water to "sweeten" the filters and increase filter efficiency is giving great promise and will be reported later in detail by R. W. Fitzgerald of Norfolk, Va. and R. W. Haywood of Easton, Pennsylvania.

(Presented before the Virginia Section meeting, July 12, 1934.)

STREAM-GAGING ACTIVITIES IN NORTH CAROLINA DURING THE PAST YEAR

By E. D. Burchard

(District Engineer, U. S. Geological Survey, Asheville, N. C.)

The past decade has been a period of marked improvement in our municipal water supplies and a corresponding advance has been made in the gaging of our streams.

Review at this point will give perspective to the past year's work. Stream gaging in this State is a coöperative undertaking between the United States Geological Survey and the North Carolina Department of Conservation and Development. The Geological Survey supplies the personnel, defines the standards of accuracy and publishes the daily flow in annual reports. The State and the Survey agree on the streams to be measured and define the scope of the work. The State may also publish the data.

Ten years ago there were 26 gaging stations in operation in North Carolina, 5 of which were equipped with recording instruments and 2 with cableways for metering. Records were published as late as 4 years after their date of collection. Information was available mostly on our western streams, still undeveloped for power. No data were available for water supplies. Through municipal coöperation with the State this condition was rectified and numerous stations were established on the smaller streams that are so important for such supplies. In this work our State was a pioneer. Now similar work is being done in many sections of the country.

On the heels of this work coöperation was established between the Geological Survey and the Army Engineer offices for the establishment of gaging stations in the Piedmont and coastal sections of the State, the latter an area previously untouched by our work. This was a part of the investigation of our rivers authorized by the Congress (House Document 308). Under this investigation our first permanent gaging structures were installed.

With increasing annual allocations of State funds our gaging program was built up to a total of 77 stations in 1930. Then with the

depression our funds shrank, and retrenchment became necessary. Both the personnel and the number of stations were reduced three times in succession. Last year a minimum was set for maintenance on a "shoestring" basis, in the hope that a change in conditions would bring increased funds from the Legislature convening in January. This limit represented 69 gaging stations, 45 of which are recorder-equipped. Along with this program records are being kept up to date and are now forwarded to the printer within a year after their collection.

This is no mean showing over a ten-year period, despite the shrinkage. Two points are worth noting—(1) that all funds for the construction of recorder installations were advanced either by municipalities or by the War Department, neither the Geological Survey nor the State having funds for such improvements; (2) that gaging stations have a high mortality despite the essential need of continuity of record. In this decade 10 of the original 26 stations have been discontinued for one reason or another. Of the 77 stations maintained in 1930, 8 have been discontinued for lack of funds. This inability to continue records constitutes a major problem.

This situation we faced was presented at the last Association meeting. Within a month the picture was entirely changed, owing to new support from Federal agencies. The Tennessee Valley Authority needed intensive investigation of our western streams tributary to Muscle Shoals. During drought periods the flow past our stations on these streams constitutes a major portion of the minimum flow at that point. Moreover a large proportion of the additional headwater storage for Muscle Shoals is located in this State. Coöperation was arranged with the Tennessee Valley Authority for additional maintenance work amounting to $7,000 and a construction program under which 13 existing or abandoned staff-gage stations were to be replaced by permanent concrete installations equipped with recording instruments of the latest type. Included in this program were also 9 new stations of similar type and 11 cable-ways for metering. Materials for this work were purchased by the Authority, and labor was paid from a special C.W.A. fund set up by the Authority.

The Public Works Administration had in the meantime allocated $15,000 to this State for the rehabilitation of existing gaging stations. This was half of the estimated cost of the work exclusive of stations

reconditioned by the T.V.A. A further allocation of $3,000 of similar funds was transferred to the Geological Survey by the Weather Bureau for rehabilitation of its gages in this State. An additional allocation of $17,000 of Public Works funds was set up for the installation and operation of 6 gaging stations in an intensive study of run-off and silt movement on the soil-erosion project at High Point.

Before much of the program above outlined was under way coöperation was obtained from Mrs. O'Berry, State administrator of the Civil Works Administration, for rehabilitation of all remaining gaging stations. All C.W.A. work was hampered after February 15 by the reduction in working hours, and after March 15 by the withdrawal of Federal funds for the purchase of materials. Despite this setback 9 stations were equipped with modern concrete installations and 5 timber stations were relined with concrete for permanence. Mrs. O'Berry was of great aid in furnishing four engineers and a clerk under relief employment for work in preparation of our accumulated field data. This force was employed from January to June and did much toward getting out our last year's stream-flow data on schedule time. The combined C.W.A. and P.W.A. program furnished an equivalent of a year's work for 11 engineers and 45 laborers.

Two additional stations have been completed recently for the T.V.A., and another is under construction. Coöperation has been arranged with the T.V.A. for maintenance this year of 35 stations in which it is interested. The contract, however, requires the expenditure of half of our Geological Survey and State funds on these same stations, thus making maintenance work unbalanced between the eastern and western stations.

This program occupied the entire time of our personnel and has left much routine work still unfinished. However, as a result of the program, our gaging stations have been modernized and placed on a permanent basis almost overnight. There are now 90 gaging stations in North Carolina, all but 4 of which are equipped with recording instruments. In addition we have installed 46 cableways for metering and 10 rating controls or flumes. Office work is behind schedule, but with favorable weather this should be caught up before the end of the fiscal year.

Owing to the national emergency relief program we have attained during the past year a degree of excellence in equipment comparable with that of any other State and one that could not have been attained

even with liberal State appropriations over another 10-year period. We now have an investment in gaging station equipment exceeding $90,000, all paid from special Federal funds. To realize fully on this expenditure, State support must be obtained for adequate maintenance. The change in situation from last year is not that we do not face the same problem, but that we stand to lose more by failure to obtain funds that will assure continuity of existing records.

(Presented before the North Carolina Section meeting, November 13, 1934.)

MENACE OF SOIL EROSION

By J. H. Stallings

(Regional Director, Soil Erosion Service Department of the Interior, High Point, N. C.)

No phase of our national life occupies a more dominating position of positive influence on our community, state and national well being than that of combined farming interests, and no national resources or asset outranks in importance our inventory of agricultural lands.

The fact is, that the indispensable cropping and grass lands of the country, administered in ownership and operation by sturdy, patriotic and purposeful farmer-citizens, constitute the abiding bulwark of our state and national safety and security.

Of momentous importance, therefore, is the protection of this most valuable and basic resource from impoverishment and wastage by unrestrained erosion, if we ever expect to establish a stable foundation upon which to build a permanent farming regime of surer and better economic and social standards.

Investigation produces positive evidence that the people of the United States generally are indifferently permitting their sloping farm lands to become depleted of the reproductive topsoil, and then to be further impoverished or destroyed by the relentless action of uncontrolled gullying. This wastage is proceeding in America faster than with any race or people, civilized or barbaric, in the history of the world. Land deterioration has very markedly influenced, and even determined, the actual destinies of nations. It seems conclusive that strong agricultural soils form an essential basis of national greatness and their wise utilization, a sustained national security.

Careless, haphazard, erosion-inducing farm practices of tillage and cropping have taken severe toll of our good farm areas, and the alarming situation is that the same inefficient methods are still in general use over most of our highly erosive regions; and there is no widespread concern about it.

In the Piedmont section of Georgia and the Carolinas, hardly less than 60 percent of the upland has lost from 4 to 8 inches of its soil

and subsoil, while many of the gullies have been cut down to bed rock. It is astonishing that 50,000 farms in this area were abandoned between 1920 and 1930, and that nearly half the rural population in some of the counties migrated to cities or to other parts of the country.

Each year erosion removes from our clean-tilled crop lands 20 times as much plant food as is removed by the crops that are grown. This is a terrific drain on soil productivity, but the loss would not be so hopeless in itself; for farmers could restore that loss by employing commercial fertilizers and growing soil-improving plants, but the tragedy is that erosion not only removes the plant food, but it actually steals away the soil body itself, with all essential elements of humus, microörganisms and other materials necessary for holding soil moisture and making plant food available.

Every rainfall heavy enough to cause any surface runoff carries away a film of soil from lands that are under cultivation. Thus, there is a continuing attack on the valuable thin surface layer of the topsoil, averaging only seven or eight inches in depth over the uplands of the nation. This topsoil, it should never be forgotten is the most productive part of the land, and the farmers' principal capital. It is this thin layer that constitutes the main storehouse of all farm revenue, and it is to this storehouse that the farmers must look for any degree of prosperity that he may hope to achieve for himself and his family.

It is a national tragedy that we have lost through destruction not less than 35,000,000 acres of erstwhile good agricultural land, the equal of 220,000 farms of 160 acres each, or a total land area one and one-third times the size of the State of North Carolina—enough to support in modest comfort many millions of people. Hundreds of thousands of acres are being constantly and viciously attacked, impoverished and at least partially destroyed each year.

But even that is not the most serious or distressing aspect of the erosion situation. A far bigger national calamity looms definitely ahead on the 125,000,000 acres of cultivated land from which erosion has already removed a very large percentage of the productive topsoil and which will surely go out in complete impoverishment and destruction as far as any practical farm utilization is concerned, unless corrective control measures can be effectively installed to avert the disaster.

And this gripping thought, likewise, must be constantly in mind; that all the while on these rapidly eroding and wasting lands, there

are hundreds of thousands of families fighting a losing battle against poverty, drudgery and hardship at their own doors, because their lands are being insidiously robbed of their productiveness by the scourge of erosion, and relentlessly washed away.

There are even areas now classed as rural slums, where want and poverty meet in utter destitution, the equal of a city's lower world desolation; spots where living is hard and crude and raw, and where mind and body succumb to mal-treatment in a low vitality.

An area totalling 1,506,111 acres in 40 Piedmont and mountain North Carolina Counties has reached the gully stage, according to a reconnaissance erosion survey made by the Soil Erosion Service. Out of this number 804,270 acres have been abandoned because of excessive erosion and an additional area comprising 2,135,407 acres has been severely eroded and is on the verge of complete destruction.

Anson County leads the list with 108,723 acres abandoned due to excessive erosion and an additional 70,800 acres in the gully stage. 58,237 acres more are so severely eroded that they are bordering on the brink of destruction. More than 52 out of each 100 acres in this county have reached the gully stage.

North Carolina farmers lose 66 million dollars annually from erosion. That does not include the cost of the stupendous damage that rainwash does to highways and railways, in silting up city water-supply reservoirs, and the clogging of stream channels.

EFFECT ON STREAMS

The extent of this destruction may be visioned by looking at the Mississippi, which in the ordinary transaction of its business, and not taking into account the havoc that it creates when it goes on a tear, annually dumps the fertility from 1,250 farms of 160 acres each down into the Gulf of Mexico, from which watery grave we can never salvage it.

Every other stream in the United States fed by rain water running down plowed or cleared slopes does the same kind of job, to the end that our loss in farm value every year amounts to such a staggering total that it would take an astronomer to figure it. It is a loss, however, that in certain locations is actually visible to the naked eye. One can see it by looking at the large quantity of good earth from farm land that is piled up behind reservoir dams.

For example, 11 out of 13 power reservoirs built along upper Deep River have been filled to capacity with products of erosion in the last

40 to 50 years. One of these was filled within 31 years. The dam across the Colorado River at Austin, Texas, filled up with mud to 85 percent of its storage in 20 years. Again, the Elephant Butte reservoir in New Mexico, which provides irrigation water for one of the largest projects in the West, is being ruined at an alarming rate. When the Reclamation engineers built this reservoir, at a cost of about $10,000,000, they said it would have a life of 233 years. They were somewhat in error, for as recent measurements have shown, that reservoir will, within 60 years from today, be packed so full of alluvial soil brought to it by erosion that it will not hold enough irrigation water to supply its customers for even one year.

Surveys recently made by the Soil Erosion Service show that the capacity of the City Reservoir of Spartanburg, S. C., is being reduced at the rate of 2.14 percent per year; that at High Point at the rate of 2.26 percent; and that of Greensboro at about 1 percent per year.

Stating it another way, the area draining into the reservoir is emptying soil into it at the rate of 2.15 tons per acre per year at Spartanburg; 2.07 tons at High Point, and 1.23 tons at Greensboro.

The future outlook would be very gloomy indeed if it were not for discoveries brought to light through research during recent years.

On the basis of silting studies carried on by Army Engineers, it is estimated that silting in reservoirs on the Chattahoochee river may be expected to progress at the rate of 45 acre-feet annually for each square mile of catchment area.

Forests and woodlands offer the best means nature has provided to store and conserve water. The water of percolation is increased and the surface runoff is reduced in forest areas.

When rain falls on a bare field 30 to 40 percent of it runs off carrying with it, in many instances, as high as 40 tons per acre of our best top soil. But when rain falls on forest land a different story results. Careful records kept by soil erosion experiment stations all over this country and abroad show that less than 1 percent of the water runs off of a forest area, and less than 80 pounds per acre of soil are carried away. From these records it is shown that a forest saves 400 times more water and 4000 times more soil.

Results obtained at the Soil Erosion Experiment Station at Statesville during the last three years show that bare land lost 65.43 tons of soil per acre, and 31.87 percent of the total rainfall as runoff per year. Similar land planted to cotton lost 17 tons of soil per acre and 8.98 percent of the rainfall as runoff. Lespedeza lost 0.49 ton of soil

per acre and 5.5 percent of water as runoff while forested land lost only 2 pounds of soil per acre and less than 0.1 percent of rainfall as runoff.

The Southern Forest Experiment Station at New Orleans, La., indicates that for 103 rains over a period of 2 years, totalling 131 inches of rainfall, the average loss from unburned oak forest was 1 percent, while from barren abandoned land 32 percent, and cultivated cotton 39 percent.

Forest cover plays an important part in the amount of rainfall lost as runoff, as is evidenced by the findings of a number of Experiment Stations.

During a certain period at the Soil Erosion Experiment at Guthrie, Okla., an unburned forested area lost 250 gallons of water as runoff while a corresponding plat, equal in size, which had been burned lost 27,600 gallons. For an average of four years the burned area lost 4.96 percent of the total rainfall as runoff while the unburned area lost 0.13 percent. The burned area lost over 38 times as much water as the unburned.

The ground cover has a direct bearing on the rate of loss of soil by erosion and silting of reservoirs. The Morgan Falls plant of the Georgia Power Company on the Chattahoochee River is below large cultivated barren areas. After ten years the reservoir was filled, leaving only a narrow channel through the delta for the river to flow. On the other hand, the Mathis reservoir, above which there are only forests, after ten years service, shows little or no signs of silting.

The Municipal reservoir built by Raleigh in 1914 has been reduced more than one-third in capacity by silt from the cleared land which makes up a portion of its watershed. A reservoir built in 1923, the watershed of which is wooded, has been silted very slightly.

Another striking example of the effect of forest cover as runoff may be had from an incident that happened in California just a little less than a year ago. On Thanksgiving Day of last year, a fire known as the Pickens Canyon fire burned over 5,000 acres in four small canyons near Los Angeles. This was followed by a torrential rain on December 30 and 31. As a result of this, Haynes Canyon, comprising an area of around one and one-half square miles, with less than one-half square mile, burned, and a rainfall of 11.26 inches, had a flow of 1,000 cubic feet per second per square mile of area. Erosion débris was brought into the basin by the flood waters at the rate of 67,000 cubic yards per square mile of burned drainage area.

San Dimas Experimental Forest, having a total area of 17 square miles, and covered with a continuous mantle of unburned chapperal vegetation, received during the storm a total rainfall of 10.82 inches and yielded peak runoff at the rate of only 51 second feet per square mile. Erosion débris transported by this water was practically nil, amounting to only 56 yards per square mile.

At the Southern Forest Experiment Station unburned forested land lost 1 percent of total rainfall as runoff; after first burning in March, 1932 three percent was lost; and after second burning in February, 1933, the runoff increased to 10 percent of total rainfall.

At Tyler, Texas in 1933, the soil loss from unprotected sloping fields with clean cultivated crops without terraces was 41.03 tons per acre, or ⅓ inch of soil over the whole acre. A wooded area of almost same slope lost only 0.03 ton of soil per acre, thus, the cultivated area lost 1400 times as much soil.

The average annual losses in two and one-half years from a 12½ percent slope, oak timber, Kirvin soil, standard length plats were 0.74 percent runoff and 0.01 ton soil per acre. A plat adjoining burned annually had 2.55 percent runoff and 0.19 ton soil per acre erosion. So far the losses from the burned plat have been small, but an increasing erosion rate is indicated with the successive burnings.

Studies by Huffel in France show that accumulated leaf litter can absorb 2.4 to 2.8 inches of rainfall on steepest slopes. During very heavy deluges all the water can not be held but the water runs off clear.

Well decayed undistrubed litter holds water much better than freshly accumulated litter on burned areas. At the Lake States Forestry Experiment Station, one inch of litter accumulated after a fire held only 0.02 inch of rainfall while 2 inches not burned for 5 years held 0.17 inch.

Investigations in California indicate that in presence of litter (not burned) runoff is 10 to 30 times less than where litter is burned over, or removed.

Trees, catch, hold, and allow to evaporate before it reaches the ground from 8 to 33 percent of the rainfall. Leaves and twigs break up rain drops, direct them down tree trunks, forms them into mist, or gently drop them to the ground. This prevents packing and thus reduces runoff.

The litter acts as mulch retarding evaporation. Cultivated lands lose as much as 50 percent of rainfall by surface evaporation.

Dr. Huten of the Central States Forest Experiment Station finds

that the top inch of soil in a normal protected woods area absorbs 47 times as much moisture as an abandoned field; that the third inch in depth in the woods absorbed 15 times as much water and the 8th inch 2½ times as much as the same depths absorbed in the field.

Records kept by the New York State College of Forestry at Syracuse have led to the conclusion that springs in wooded areas discharge 5 times as much water as springs in cleared areas. This is due to the fact that water is retarded and impounded in the forest areas and escapes from the underground waterways more slowly, but more steadily. Many cases are recorded where the removal of large areas of forests have dried up springs completely. Much of the rain that falls on a forest is necessary for the growth of the trees.

This is substantiated further by the story of Polecat Creek, a tributary of Deep River in Randolph County:

Some 20 years ago Polecat Creek in Randolph County went dry. A gold mine and smeltering plant were operated on that stream for a number of years prior to 1914. Large quantities of fuel-wood were required. Farmers living up and down the creek stripped the land of timber to supply the gold mine. The slopes were denuded of their protective cover. Rain falling on the ground quickly ran off, taking with it fertile topsoil.

Floods and droughts came. When it rained the uncontrolled water hurried away as from off a roof, all the time taking still more soil and flooding lowlands. Precious little water soaked into the earth to maintain the moisture supply between rains.

Springs dried up.

When rain was light the creekbed virtually went dry. No water flowed along its course. Heavy rains clogged the stream channel with silt. Fields were flooded still more easily. Farmers were forced to abandon cultivation of the creek bottoms. Floods ruined the crops when it rained and desert-like dryness parched them when it did not.

Mining operations ceased in 1914. Trees began to catch hold again on the hillsides. Vegetation began to trap water once more, allowing it to soak into the earth. Springs started flowing and releasing the water slowly.

Erosion stopped.

Polecat Creek once more flows regularly. Bottom lands are producing crops again.

(Presented before the North Carolina Section meeting, November 13, 1934.)

PROPOSED GRAVITY WATER SYSTEM FOR WENATCHEE VALLEY, WASHINGTON

By Fred J. Sharkey

(*City Engineer, Wenatchee, Wash.*)

The Wenatchee river, one of the major tributaries of the Columbia River, flows through a narrow valley in the lower reaches of its course, joining the Columbia near the City of Wenatchee. This lower valley, some thirty miles in length, contains about 27,000 acres of rich alluvial land, given over almost exclusively to the production of fruit. The fruit orchards average about ten acres in area, with modern homes built on most of the orchards, the result being that the entire valley takes on the nature of a suburban community.

The incorporated cities are Leavenworth, with a population of 1500, lying at the head of the valley near the junction of the Icicle creek and the Wenatchee river, Cashmere, near the center, with a population of 1500, and Wenatchee, with a population of 12,000, near the confluence of the Wenatchee river and the Columbia. In addition to the incorporated cities, small business communities have sprung up in the valley at Peshastin, Dryden and Monitor.

Surrounding Wenatchee is a thickly settled suburban district. The district known as West Wenatchee and Millerdale, lying to the Southwest, West and North of the city is incorporated into a domestic water district with a population of about 1500 and has its own distribution system and pumping plant. South Wenatchee, where the division shops and yards of the Great Northern Railway are located, lies about one mile South of Wenatchee and has a population of about 800, and East Wenatchee, across the Columbia river in Douglas County, with a population of about 1200, is also incorporated into a water district with its own distribution system and pumping plant.

EXISTING WATER SUPPLIES

The City of Wenatchee secures its existing water supply from the Columbia River, treating the water in a modern rapid sand filter plant. The product of this plant is generally satisfactory and is

reasonably soft, having a soap hardness varying roughly from 30 to 70 p.p.m. during the different seasons of the year. Columbia river water is not difficult or expensive to treat, the entire cost from raw water to consumer averaging 2.7 cents per thousand gallons in the seven years that accurate cost records have been kept. As a source of supply however, the Columbia has the objectionable features of averaging twice the hardness of the proposed Icicle supply, of being too warm in summer, the river temperature rising to 65 degrees Fahrenheit at times, and the psychological objection of being dangerously contaminated at all times in its raw state. A further and more serious objection from an operating standpoint, is that at varying periods during the year concentrations of taste-forming algae occur. The resulting tastes are difficult to remove and add considerably to operating costs.

Leavenworth secures its supply from the Icicle Creek and is not included in the proposed project. Cashmere pumps its water from wells near the bank of Mission Creek. Presumably the water in the wells is partly surface and partly underground, for the supply is unsatisfactory due to excessive hardness, averaging 250 p.p.m. The other communities are supplied from wells and springs, and all such sources are excessively hard, being greater than that of Cashmere.

Many of the orchard homes use the water from the irrigation ditches, storing it in cisterns. These ditches are dry from November to March, so that accidental breaks or leakages in the cisterns leave the owners with the unpleasant prospect of hauling water from their neighbors or from the river. Since most of the homes have modern plumbing, the resulting inconvenience can be readily imagined. Furthermore, the ditch supplies are grossly polluted and unpalatably warm in summer. The result is that all these communities and individual homes have been actively interested for several years in securing water by gravity to supply the entire valley below Leavenworth and which could be made potable at the source and kept safe and palatably cool throughout the year.

PROPOSED SOURCE OF SUPPLY

The Icicle creek, the proposed source of supply, enters the Wenatchee river from the South near the town of Leavenworth. This creek, having a drainage area of about 200 square miles above the intake of the proposed project, flows through a narrow granite canyon in the heart of the Cascade range, and is fed by innumerable mountain

lakes and streams. Mt. Stuart, one of the high peaks in this part of the range, lies within the drainage area of the Icicle. Above the proposed intake of this project much of this area is heavily timbered, but in common with most of the timber at the higher levels on the east side of the Cascades, it is largely unsuitable for logging, and except for the possibility of a disastrous fire, the cover will probably remain comparatively untouched. Generally the canyon walls rise precipitously almost from the banks of the creek, and there is no suitable farming land along the stream. Also no mining claims of commercial value have been discovered in the canyon, or indeed in this part of the Cascades. In the past few years the water shed has been rented by the Forest Service for sheep grazing, but it is of little value, and we are assured by them that the Government land can be closed and controlled with little difficulty. The area lies within the Northern Pacific land grant, and the railway owns each alternate section. This land will gradually be purchased at an appraised value. With a controlled water shed, the stream is ideal for a domestic water supply, as noticeable turbidity is rare and of extremely short duration, the water is cold at all seasons of the year and is unusually soft for surface water in this area.

STREAM GAUGINGS AND DIVERSIONS

As is the case in all productive agricultural areas in Eastern Washington, the Wenatchee Valley depends upon irrigation for its existence. With this fact in mind, the first consideration in the investigation of domestic supplies from surface waters is the replacement of any shortage that may result to the irrigation districts caused by domestic appropriation, for the very life of the communities depends upon the assurance of ample supplies of water to the orchards. The irrigation seasons vary somewhat from year to year, but the period from March 15 to November 1 can be set as the outside limits in which irrigation will be necessary.

Water from the Icicle creek is used for irrigation of approximately 12,000 acres in the Wenatchee Valley. The discharge of the stream is ample every year to take care of all the existing diversions and the demand for this project, except during the months of August, September, and October. In some years, averaging about one in each four, there is a shortage during these months, and it was therefore necessary to investigate the possibilities of supplying such deficiency. Fortunately, there is ample excess water in the Wenatchee river at all

times to permit diversion from that stream for replacement of water taken from the Icicle Creek. There are also numerous small lakes in the Icicle water shed which present possibilities for storage. Since the proposed diversion for this project is 22 cubic feet per second or 44 acre feet per day, storage of 4000 acre feet will be ample to supply our requirements in the driest years that have ever been known. We have, therefore, three alternatives open to us by which we may take care of water shortage.

1. Construction of storage dams on some of the larger lakes in the Icicle water shed.
2. Replacement of water taken from the Icicle by this project with water pumped to the irrigation canals from the Wenatchee river.
3. Pumping water from the Wenatchee river to our own system during periods of shortage.

Since we have not had sufficient time to make the necessary investigations of storage possibilities, and have not been able to come to definite agreements with the irrigation companies, we have based our application to the Public Works Administration on the plan of pumping water to our own system. At the present time, water taken from the Wenatchee river at the mouth of Tumwater Canyon above Leavenworth is nearly as desirable as that taken from the Icicle. It is cool, clear, soft water, which would require only occasional chlorine treatment. It has, however, much greater possibility of future contamination, as the shores of the mountain lakes at the source of the Wenatchee river are rapidly being built up with summer homes, and a part of the upper river valley is suitable for farming, also the temperature of the water rises considerably above that of the Icicle in the summer months. For these reasons, it is probable that one of the other two alternatives will be used in the final analysis of this problem.

Unfortunately, stream gaugings on the Icicle during the past few years are not available, but were taken by the Geological Survey from June, 1911 to October, 1914, inclusive. These gaugings are available, but since the characteristics of the flow curve for the different years are roughly the same, only the readings of the year ending September 30, 1912 have been charted. This chart shows ample run-off for any storage necessary for this project. It shows, however, that there is a deficiency in the flow of the stream at certain periods to supply the existing diversions and the water necessary for this project.

THE PROJECT

As nearly as may be estimated from known consumption per capita at Wenatchee and Cashmere, the present maximum daily demand of the different communities to be served will be as follows:

	gallons
Wenatchee	5,700,000
Cashmere	600,000
Peshastin	200,000
Dryden	200,000
Monitor	200,000
West Wenatchee	400,000
Millerdale	100,000
South Wenatchee	300,000
East Wenatchee	400,000
Total	8,100,000

The population of Wenatchee increased abnormally during the period from 1910 to 1930, being 4,030 in 1910, 6324 in 1920 and 11,624 in 1930. Postal authorities place the present population at 12,500, an increase of slightly less than 2½ percent per year during the past four years. There are influences such as the Grand Coulee development or mining activity which may result in abnormal growth during the life of the bonds on this project, but we consider that we are not on a firm financial basis if we estimate any such abnormal growth during the succeeding thirty years. We have therefore placed the increase at 2 percent compounded annually over the district to be served, and have assumed that 75 percent of this increase would become consumers. On this basis we have designed our supply line to deliver 14,300,000 gallons per day.

In detail, the project consists of a low concrete diversion dam or overflow weir in the Icicle river at a point approximately 2½ miles above the inhabitable portion of its valley, and five miles from Leavenworth at an elevation of 1670. The dam will be 3 feet wide and 190 feet in length on the crest with maximum height of 12 feet. The upstream face will be vertical and downstream face on an ogee curve. At the North side of the dam a trash rack and control gate structure will be constructed with an operating platform above the maximum high water level. From the control gate to a point 800 feet downstream from the dam 36 inch reinforced concrete pipe will lead, where a reinforced concrete settling basin 30 by 60 feet in area and 12 feet deep will be built, containing baffles and fine screens.

This basin will be covered with a wooden structure to insure favorable winter operation and will be provided with control gates, bypass and washout lines.

The main supply line will be 25¼ miles in length, as follows: From the settling basin a 30 inch pipe line will lead five miles to the Peshastin tunnel at elevation 1570, crossing the Icicle river in a deep siphon on a steel bridge about 2½ miles below the basins. The floor of this 4000 foot tunnel will be on hydraulic grade, as will those of all tunnels on the project. Tunnel inverts will be lined with concrete up 30 inches on the side, but the tunnel sections will not be lined unless made necessary by the character of the rock.

From the Peshastin tunnel there will be five miles of 27-inch pipe and five miles of 28-inch pipe to the 600 foot Cashmere tunnel at elevation 1370. This section of the line will cross Peshastin creek canyon at two miles from the Peshastin tunnel, Brender canyon at five miles from the Peshastin tunnel, and Mission creek canyon just before entering the Cashmere tunnel.

From the Cashmere tunnel a 27-inch pipe line will lead 7½ miles to the 200 foot U. S. tunnel, crossing Fairview canyon about half way in this section. From the South portal of the U. S. tunnel a 27-inch pipe 2¾ miles in length will lead to Reservoir No. 1 at elevation 1190. This reservoir will be an open top structure of 28 m.g. capacity, 367 feet by 567 feet in surface area with side slopes 1½ to 1, and 18 feet in depth from bottom to overflow, with three foot free board. It will be lined with concrete 6 inches thick, in panels approximately 20 feet square. Joints will be laid on 4 inch by 9 inch concrete ribs coated with tar. Copper water stops of conventional design will be used at all joints, and all angles of water stops will be stamped out of sheet copper with all connections brazed. One-half inch expansion joints between panels will be filled with asphalt above the water stops. All panels will be laid alternately to permit closer inspection and correction of defects at the edges.

From reservoir No. 1 a 24-inch pipe line will lead to the syphon crossing Canyon No. 1 opposite Wenatchee, from which the pipe line feeding Wenatchee will branch, and from Canyon No. 1 a 18-inch pipe line will continue to Reservoir No. 2 at elevation 1110. This reservoir of 3½ m.g. capacity, will be of the same construction details as Reservoir No. 1, and will act as an equalizer and distributing reservoir for East Wenatchee, Millerdale and the South end of the City of Wenatchee.

The majority of the excavation in both reservoirs will be in sandstone, and berms will necessarily be made of this material to a large extent. The compacting of fills in these berms presents some difficulty, and detailed specifications have not as yet been worked out to our satisfaction. Another question that has given us some concern is the action of this hot, porous stone on the curing of the concrete lining placed in direct contact with it. We are considering the spraying of the stone with emulsified asphalt and laying concrete on this asphalt seal.

Since the bottoms of the reservoirs will be in solid rock, underdrains will not be provided.

Following the floor of the valley in the construction of the pipe line was prohibitive on account of the high heads involved and the cost of rights-of-way, therefore the line will be laid along steep, rugged mountainsides for the great majority of its length, and will be from 350 to 400 feet in elevation above the communities to be served. Several deep canyons cross the line involving heads up to 400 feet. It is proposed to use steel in all heads over 250 feet, but alternate bids will be called on continuous creosoted wood stave and steel in all lighter heads. Since the cost of wood stave pipe increases materially with increase in pressure, most of the location parallels hydraulic grade at 50 foot head.

Distribution systems are installed at present in Peshastin, Cashmere, Wenatchee, East Wenatchee and West Wenatchee, those in Cashmere and Wenatchee being complete and modern. As part of this project it is planned to install modern distribution systems at Dryden, Monitor, South Wenatchee and Millerdale, and $237,900 have been allocated for this purpose in the estimate of cost of the project. Detail plans of these systems will not be worked out until after the project is under way, as they involve no engineering difficulties and it is planned to time their completion to coincide with the completion of the main project. Each small community will be provided with an equalizing reservoir of sufficient capacity to provide ample storage for fire protection and to secure continuous service.

FINANCIAL

The estimated cost of the project is $1,154,700 divided as follows:

Intake weir, control works, settling basins and connecting pipe line	$36,700
Main line pipe, excavation and structures	507,800

Tunnels	$81,900
Reservoirs	205,700
Relief pump station and pipe line	32,700
Distribution systems for outside communities	237,900
Engineering	25,000
Rights-of-way and legal expense	10,000
Interest during construction	17,000
	$1,154,700

Application for P. W. A. funds has been filed and has been approved by the Washington State department and transmitted to Washington, D. C. for final approval and allotment of funds. Of the funds required, we are assured that $335,000 or 30 percent of the cost will be furnished us as a grant from the Public Works administration. Revenue bonds bearing 4 percent interest pledging the assets and revenues of the plant for the remaining $819,700 will be accepted at par by the government.

Thirty-year revenue bonds will be issued, with amortization starting the second year, which will require an annual charge for principal and interest of approximately $50,000 during the remaining 29 years of the life of the bonds.

Cost of distribution systems to outside communities will be reduced by their proportion of the grant, requiring them to return $168,900 of the $237,900 cost of such systems. Interest and amortization of their proportion of the bonds will amount to $10,300 annually.

On the basis of past cycles of dry years, it is estimated that replacement of water by pumping will be necessary one year in each four, and that pumping costs each such year will be $10,000, or an average of $2500 yearly.

Water will be furnished to each outside community over a master meter, and will be sold to such communities at a rate per 1000 gallons that will return sufficient to pay main line costs and interest and amortization of funds used in the construction of connecting lines and distribution systems for such communities. Each such community will be required to incorporate its own water district and contract with Wenatchee to furnish water for thirty years, or the life of the bonds. Such communities will handle their own maintenance and finances. Since the cost of interest and amortization of the bonds used for outside distribution systems will be returned to Wenatchee through excess water rates, the net annual cost to Wenatchee of bond interest and amortization for the project will be as follows:

Total annual bond charges	$50,000
Less bond charges returned by outside communities	10,300
Net annual bond charges	$39,700

Extra annual costs of operation of the Wenatchee plant which are chargeable to this project are estimated as follows:

Power for pumping	$2,500
Chemicals	1,000
Maintenance supplies	3,000
Labor and clerical help	7,700
Superintendence	2,000
	$16,200

Rates for water have been tentatively set as follows:

gallons per day	*cents per 1000 gallons*
First 500,000	6
Next 500,000	5
Next 500,000	4
All over 1.5	3

Since none of the communities outside Wenatchee will use 500,000 gallons per day, the billing of all such communities will be at the rate of 6 cents per thousand gallons for bulk water. The average daily consumption for Cashmere and Wenatchee, based upon metered records, is 230 gallons per capita, this excessive consumption being caused by the large amount of water used for sprinkling in the summer.

Based upon careful estimates of consumer population and upon tentative contracts signed by outside communities, there will be 18,800 consumers on the system at the time of completion, 12,000 in Wenatchee and 6800 in outside communities. At the rate of 230 gallons per capita per day, the annual demand of these 6800 consumers will be 570,860,000 gallons. The bulk revenue from this demand at 6 cents per thousand gallons will be $34,200 annually.

Annual operation of the Wenatchee filter plant, which can be applied to the operation of this project is $37,500.

Roughly, the anticipated financial set up of the project after completion will therefore be as follows:

Revenues:

Bulk water revenue from outside districts	$34,250
Operating savings of existing Wenatchee plant	37,500
	$71,750

Expenses:

Annual operating costs	$16,200	
Net annual bond charges	39,700	55,900
Surplus		$15,850

These figures are for the present population of the district and it is obvious that increases in revenue due to increased population will not entail a proportionate increase in operating expense.

While the product of the Wenatchee filter plant is satisfactory and the cost of treatment reasonably low, we anticipate several advantages from the construction of this system. Primarily, it will set up a work project which will take care of our unemployed for a year, as it is estimated that $350,000 will be spent for local labor. It will insure safety for the entire district from an epidemic of water-borne disease. It will substitute soft water for the medium hard and hard waters now in use, with saving in labor in the kitchen and in laundry work, and with substantial cash savings in the expense for soap. It will permit doubling the population of the district without increase in capital investment for supply lines and structures. It will insure lower water rates in the future. It will provide fire protection, which is negligible at present, for all the small communities under the project, with considerable saving in insurance rates. Finally, it will insure a continuous, safe and adequate supply of water to the entire Wenatchee valley for an indefinite period in the future.

(Presented before the Pacific Northwest Section meeting, May 11, 1934.)

LIST OF SECTION PAPERS

Indiana Section

Antler's Hotel, Indianapolis, Ind., March 6, 7, 8, 1935

March 7, 1935

March 8, 1935

Purification Plant Operators' School

Wednesday, March 6, 1935

Chlorination Problems............................E. F. Kinney, C. D. Adams
Pumps, Valves and Meters......Walter Decker, A. R. Kline, L. D. Klinker
Filter Washing..Neil Kershaw

New York Section

DeWitt Clinton Hotel, Albany, March 21 and 22, 1935

History of the Albany Water Works, Including General Description of the New Water Supply System..........................Theodore Horton
Description of Albany's New Filtration Plant
Benjamin Smith, Gustav J. Requardt
Synura Troubles at Albany..........................George E. Willcomb
Some Observations Based Upon Forty Years' Water Supply Experience
Wm. W. Brush
Water Rate Cases Before the Public Service Commission of New York
A. H. Pratt
The Art of Planning as Related to Watershed Control..........M. W. Cowles
Water Works and the Relief Program..........................R. W. Sawyer

Canadian Section

Hotel London, London, Can., March 27, 28, 29, 1935

Mechanical Control in Water Works Operation..............A. H. R. Thomas
Flushing of Water Mains................C. E. Brown, C. G. R. Armstrong
Design, Construction and Operation of 40 Million Gallon Filtration Plant for the City of Hamilton..........................W. L. McFaul
Development of Municipal Ground Water Supplies..........W. B. Redfern
Thawing of Ice in Water Pipes by Electricity................W. P. Dobson
Pipe Laying in Rock Formations..................................F. G. Browne
Problems in Water Filtration Operation
F. P. Adams, Wm. G. Hunt, D. H. Matheson, E. W. Johnston, W. R. Edmonds
General discussion on Water Works Problems.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Better Boiler Water: What Has Been Done about It. R. C. BARDWELL. Railway Engineering and Maintenance, 30: 9, 476–479, 1934. General review of railroad water treatment indicates that approximately 40 per cent of boiler water now being used on American Railroads is receiving either internal or external treatment.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Mountain Waters Impose Unusual Problems. RAY MCBRIAN. Railway Age, 96: 22, 805–806, 1934. Denver & Rio Grande Western Railroad had trouble from formation of silicate scale in locomotive boilers operating between Alamoso, Colo., and Farmington, N. M., and between Salida and Montrose, Colo. Mountain waters used contained low dissolved mineral solids, but silica, varying from 0.18 to 4.71 grains per gallon, resulted in hard destructive scale. Treatment with sodium aluminate precipitated silica in form that could be blown out without damage to boilers.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Modern Equipment Reduces Cost of Water. A. W. JOHNSON. Railway Engineering and Maintenance, 30: 4, 213–215, 1934. Modernization by Atchison, Topeka and Santa Fe Railroad of its water supply facilities at Topeka, Kans., has resulted in reduction of approximately 40 per cent in cost of water. Twelve 10-inch by 70-foot wells, operated by steam-driven plunger pumps have been replaced by three 24-inch concrete-cased wells with vertical centrifugal pumps, each furnishing 1000 g.p.m. Wells were installed by sinking 42-inch Armco iron casing to bed rock by open-caisson method and inserting the 24-inch (inside diameter) concrete casing and well screen; after which, iron casing was pulled. From cistern 104 feet in diameter, into which well pumps deliver, water is pumped through distribution system by 4 horizontal centrifugal pumps ranging from 300 to 1400 g.p.m. as required, or by 1500 g.p.m. fire pump. Location and detail plans are given.—*R. C. Bardwell*.

Automatic Softening Plant Handles Polluted Water. Anon. Railway Age, 97: 8, 229–231, 1934. In 30,000-gallon per hour lime-soda water softening plant installed by Nickel Plate Railroad at its Ft. Wayne, Ind., terminal, copperas and sodium aluminate are being used to coagulate and remove high amount of organic pollution which is frequently present in St. Marys River. Copperas is applied in raw water discharge line and sodium aluminate with lime and soda

ash in mixing box at top of softening tank. Results show consistent satisfactory removal of both scaling matter and organic pollution. Detail plans show chemical equipment installation.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Disposing of Sludge. E. M. Grime, J. T. Andrews, and C. P. Richardson. Railway Engineering and Maintenance, 30: 6, 334–336, 1934. Sludge disposal is frequently one of most perplexing problems connected with design and operation of lime-soda water softening plant, one ton of dry sludge being equivalent to 6 cubic yards of wet material. Where suitable natural waterway is not available, basins arranged for periodic cleaning must be provided. In some cases, special sludge disposal cars are used.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Filtering Water. J. H. Davidson, E. M. Grime, and C. R. Knowles. Railway Engineering and Maintenance, 30: 7, 391–392, 1934. Excelsior filters formerly used extensively in railroad lime-soda water softening plants have been eliminated from later installations as superfluous, by correct chemical proportioning and adequate mixing and settling periods. Sand filters are used infrequently. Advisability of such installations depends upon local conditions.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Illinois Central Improves Method of Handling Boiler Water. E. Von Bergen. Railway Age, 96: 14, 507–509, 1934. By systematic blowing on the road, based on hydrometer tests made at conclusion of each engineman's run, Illinois Central Railroad claims to have effected economies of over $200,000 per annum, boiler water being kept within desired concentration limits and foaming prevented. Small water testing laboratories were installed at 56 terminals and hydrometer tests are made on boiler waters of all incoming locomotives. Hydrometers are graduated to read concentration in grains per gallon and chart is provided showing blow-down required to maintain concentration below critical point of 150 grains per gallon. Boiler washing is thus avoided, except at monthly inspections, and enginehouse efficiency and locomotive utilization are increased.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Water Pipe Installation and the Law. Leo T. Parker. Water Works Eng., 87: 5, 208, March 7, 1934. Courts have consistently held that owner of property abutting on a street may use space under the street to its center, so long as he does not interfere with superior right of municipality below the surface for public underground facilities. In every case court ruled that property holder could use it for necessary public utilities. Municipalities have power to require contractors to post bond to pay for water used during construction work. Several cases cited where neither water corporation, or municipality, is required to pay for extra work on a contract unless such work is authorized in strict accordance with terms of contract.—*Lewis V. Carpenter*.

Laying Intake Line in Deep Water. W. S. Williams. Water Works Eng., 87: 5, 211, March 7, 1934. Describes method of laying 30-inch steel intake

pipe for water supply of Traverse City, Mich. Pipe, purchased in 40-foot lengths, was lowered to diver from derrick scow by caterpillar type of crane. Bolted socket joint with retaining shoulder was used and had sufficient flexibility to permit the line to adjust itself to slight irregularities in contour of lake bed.—*Lewis V. Carpenter.*

Welding Generators Thaw Frozen Mains. Anon. Water Works Eng., **87**: 6, 270, March 21, 1934. Arc-welding generators are extremely well suited to thawing frozen mains. Leads of generator are connected to the pipe and the heavy current melts the ice. With 250 amperes, ¾-inch pipe 300 feet long will be thawed in from 3 to 10 minutes and with 500 amperes, a 3-inch pipe, in less than an hour. For thawing copper services, higher current density is needed than for lead or steel.—*Lewis V. Carpenter.*

New Plant Ends Taste Troubles. Anon. Water Works Eng., **87**: 6, 264, March 21, 1934. Describes equipment used in new 8-m.g.d. rapid sand filter plant for Easton, Pa., which takes its supply from Delaware River. Plant has mechanical mixers and provision for dry feeding of lime, alum, and activated carbon.—*Lewis V. Carpenter.*

Appropriating Private Property. Leo T. Parker. Water Works Eng., **87**: 7, 316, April 4, 1934. Most state laws authorize municipalities to condemn and acquire land, provided that (1) appropriation is public necessity; (2) just compensation is allowed to property owner; (3) definite time allowed for appeal; and (4) compensation is based on actual losses. One water company can appropriate water rights of another water company if a necessity exists and complaining company must make a prompt appeal from the appropriation. Courts have held that municipality may compel, if unwilling, private water company to sell water plant serving said municipality, at price to be determined by courts. Various courts have held that purchaser of real property is bound to examine the records of recorded deeds; also, that such purchaser is bound by any contract or defect in the title, if it can be shown that he was aware of such defect when contract was signed. Cites case where railroad siding conveyed an unrecorded right of way agreement.—*Lewis V. Carpenter.*

Famous Victims of Water-Borne Diseases. James A. Tobey. Water Works Eng., **87**: 7, 308, April 4, 1934. Earliest recorded death of great monarch from water-borne disease was that of Louis VIII. His son and successor was also a victim of dysentery. The wife of John Adams, Zachary Taylor, and many others were notable American victims of typhoid fever. William Shakespeare probably died of typhoid fever. Two daughters of Louis Pasteur, the founder of modern preventative medicine, died of this disease, and one of his assistants, of cholera. Author recounts the advances in water purification which have reduced typhoid death rate to a very low figure.—*Lewis V. Carpenter.*

Phosphoric Acid in pH Control. Roger C. Higgins. Water Works Eng., **87**: 8, 360, April 18, 1934. Chillicothe, Mo., supply is from stream varying

in hardness from 100 to 300 p.p.m. Lime dosage is increased when hardness increases and water is softened, but gas formers would persist, even when chlorine residuals of 0.3 to 0.45 p.p.m. remained after 8 hours: lime dosage would be 9 to 10 grains per gallon, and resulting pH, about 9.3. About 2 grains per gallon of alum is added and enough phosphoric acid to lower pH to about 8.4. Alternative treatment using soda ash was shown by trial to be twice as costly. Acid is fed from stoneware jar through glass siphon. Seventy-five percent volatilized grade of acid was found to be best suited. Advantages claimed are: (1) safe, easy method of reducing pH; (2) less alum required; (3) carbon dioxide liberated effects partial recarbonation; and (4) absence of undesirable products, such as result when sulfuric acid is used. Some analytical data are given.—*Lewis V. Carpenter.*

Activated Carbon Application in Water System Without Filters. E. J. Anderson. Water Works Eng., **87:** 8, 369, April 18, 1934. When water supply for Tyrone, Pa., from mountainous reservoir, during November 1933, developed distinct fishy taste, entire reservoir was given chlorine dosage of 1.8 p.p.m. in form of hypochlorite, after which 2 p.p.m. of activated carbon was applied as slurry, from barrels. Algae tastes were completely eliminated and high chlorine dose so reduced by carbon as to pass unnoticed by consumers. Reservoir was allowed to stand for five days after application of the carbon.—*Lewis V. Carpenter.*

The Decomposition of Sodium Bicarbonate. R. Stumper. Ztschrft. f. anorg. u. allgem. Chem., **210:** 3, 264, February 1933. Thermal decomposition of bicarbonate in boiling aqueous solution of sodium bicarbonate is reaction of first order, whose rate is determined by evolution of carbon dioxide. Increase in soda concentration with boiling slows down decomposition; time for complete decomposition increases with increasing initial concentration. Even when carbon-dioxide-free air is bubbled through, evolution of carbon dioxide is hindered by carbonate alkalinity. With exception of powdered iron, addition of coarsely dispersed substances had no effect on velocity of decomposition, but organic colloids accelerated it. Decomposition of calcium bicarbonate solution was, however, influenced by all substances added. Effect of colloidally and coarsely dispersed substances on thermal decomposition of calcium bicarbonate is not a catalytic, but a precipitation, reaction, which can be represented as follows:

$$\begin{array}{ccccccccccc} Ca^{++} + CO_3^{--} & \rightarrow & CaCO_3 & \rightarrow & CaCO_3 & \rightarrow & CaCO_3 & \rightarrow & CaCO_3 & \rightarrow & CaCO_3 \\ & & \text{dis-} & & \text{super-} & & \text{nucleus} & & \text{amor-} & & \text{crys-} \\ & & \text{solved} & & \text{saturated} & & \text{of solid} & & \text{phous} & & \text{talline} \\ & & & & & & \text{phase} & & \text{colloid} & & \end{array}$$

Thus coarsely dispersed substances act as nuclei, hastening the solid phase; colloids delay it by protective colloid action. Iron accelerates decomposition in both cases; attributable, probably, to hydroxyl ion formation.—*Manz. Translated by Selma Gottlieb.*

The Water Supply of the Palatine Middle Rhine Group. H. Holler. Ges.-Ing., **55:** 46–47, 547, 564, 1932. For convenience of common water supply, a

number of townships have organized themselves into a utility group. Water required, 10.5 gallons per second, is obtained from five wells drilled 79 to 82 feet into Rhine flats and fitted with copper strainers of 19 inch inside diameter. Water contains from 0.6 to 2.5 p.p.m. of iron and from 0.2 to 0.5 p.p.m. of manganese. Electrically driven low- and high-service pumps, two each of 13.2 and 18.5 gallons per second capacity, respectively, have been provided. For reserve, a Diesel engine of 85 h.p. is provided. Water is sprayed through 72 nozzles to height of 11.5 feet, for aeration, settled in 92,400-gallon basin, corresponding to detention period of 1½ to 2 hours, from pit adjoining which it is forced through 4 pressure filters and into distribution system by the high-pressure pumps. Each pressure filter, made of copper-bearing iron, contains two filter-beds, one over the other, which serve to remove iron and manganese. With flow of 13.2 to 18.5 gallons per second, rate of filtration is from 183 to 264 gallons per square foot per hour. After 165 hours run, upper filter-bed, mechanically raked, is washed with about 7000 gallons of water and after 500 hours run, the lower, with about 2600 gallons. To equalize the demand, two elevated reservoirs, of 26,400 and 140,000 gallons capacity, are used.—*Manz. Translated by Selma Gottlieb.*

Determination of the Radioactivity of Mineral Water. L. Fresenius. Ztschrft. f. Kurortwissenschaft, 2: 5, 281, 1932. Total radiation and radiation of individual elements are determined. From the half-period value, determined by the usual means, can be calculated whether radon is present alone, or with other radioactive elements. If radium is present, the half-value is larger than for radon; if thorium, it is smaller. For confirmation, sample is freed from radon, and radium content calculated from radon present after thirty days.—*Manz. Translated by Selma Gottlieb.*

The Use of Activated Carbon in Water Purification. Curt Müller. Wasser u. Gas, 23: 9–10, 248, February, 1933. In water purification granular activated carbon is used in both molded and unmolded forms. Molded carbon is made from various raw materials by chemical-thermal processes and cut to uniform size in a wire-cutting press. It has greater hardness, higher apparent density (350 to 500 grams per liter) and offers less resistance to flow of water, but is essentially more expensive. Unmolded carbon is made mostly from charcoal, occurs in leaflets, is softer, has lower apparent density (200 to 250 grams per liter), and costs only one-third as much as molded. Products of equal adsorption capacity are, however, available in either make. For evaluation of a particular kind for removal of odor and taste producing substances, chlorophenols, etc., adsorption capacity is determining factor; for dechlorination, half-period value and fatigue factor are important. Dechlorination is a chemical process, half-period value for which falls with increasing fineness of grain; but fatigue factor depends chiefly on nature of carbon. Advantages of molded carbon are compensated for in its lower average adsorption capacity: even with good pre-treatment of water a certain adsorption capacity is required. Closed filters for granular carbon have hitherto been constructed much like pressure filters. Downward flow allows simpler and cheaper construction and more efficient backwashing, due to loosening of carbon bed at

suitable rate of wash. During washing, rearrangement takes place, so that some partly used carbon from bottom is displaced toward top. With upward flow, carbon must be confined between screens fine enough to prevent rearrangement; this also protects the comparatively fresh upper layers from contaminated condensate during steam treatment of bed. It is evident that pressure type carbon units for dechlorination and taste and odor removal can, at slow rates of flow of 2 to 10 meters per hour, also be used for removal of oil from condensate and for benzene recovery. The American practice of using powdered activated carbon has this disadvantage, that the adsorption capacity of the carbon is not fully utilized. The Carbon-Norit-Union method uses a form of layer filtration in which, after backwashing of the filter, an aqueous carbon suspension is applied to the surface and worked into the top 10 to 15 cm. by rake, by plow-like scraper, or by use of compressed air, while water is drawn off. In this way the carbon comes in contact with the water only after the practically complete removal of suspended matter. Contact in the upper layers of the sand gives better utilization of the adsorption capacity, since the taste producing substances are concentrated in the upper layers. This procedure causes no additional loss of head, and effected complete removal of chlorophenols during the filter run with carbon dosage of 6 grams per cubic meter (6 p.p.m.), while continuous application to filter influent required 12 grams. This method also gave better utilization of the carbon in dechlorination.—*Manz. Translated by Selma Gottlieb.*

Turbidimeters for Water. CH. M. WICHERS and J. E. JAKOBS. Ges.-Ing., 55: 610, 1932. For routine control the Middendorp apparatus is convenient and sufficiently accurate. If great accuracy is required, the Moll apparatus is better. The Middendorp instrument should be frequently standardized against the Moll, for the water in question. The curve should not be made up for American units, but for percent of light absorbed by water column of 80 or 100 mm. Curves for various liquids show considerable differences between the two instruments, probably due to physiological factor in use of Middendorp apparatus, which is eliminated in the Moll nephelometer.—*Manz. Translated by Selma Gottlieb.*

Sterilization of Pool Water with Katadyn. VIESOHN. Ges.-Ing., 56: 27, 316, July, 1933. In Frankfurt-a.-M. stadium, the non-swimmers' basin of 423,000 gallons capacity was experimentally treated with electro-Katadyn apparatus after emptying and cleaning. The apparatus has sheet silver electrodes of special design, past which the water flows. Current of two amperes at 4 to 4.5 volts was used, with reversal of flow every fifteen minutes. With water temperature of 12° to 17°C. and silver dosage of 100γ per liter, it was found that silver content of pool water was considerably below that calculated from loss at electrodes, because of precipitation at pool walls and in filters and also probably by reducing substances. It is necessary to use 200 to 400γ per liter to begin with, until pool water becomes bactericidal; from then on, 50γ per liter every two days is sufficient. The coli test of the water was regularly negative in 1-cc. portions. Water retains its bactericidal properties for some weeks after discontinuance of treatment. Algae growths in

pool, however, were only slightly reduced.—*Manz. Translated by Selma Gottlieb.*

Control of Chlorinous Odor of Indoor Chlorinated Swimming Pools. Fritz Ditthorn. Ges.-Ing., 56: 26, 406, July, 1933. At pool in Berlin, gaseous chlorine, measured by usual equipment, was passed through an absorption tower containing marble chips over which water flowed. The hydrochloric acid was neutralized by the marble and the chlorine converted into odorless hypochlorous acid. The irritating chlorinous odor was eliminated, bacteriological tests of the water showed gelatin counts of 0 to 14 per cc., and coli tests were regularly negative in 100-cc. portions.—*Manz. Translated by Selma Gottlieb.*

Ground Water Replenishment. Five Years' Experience in Curslack. W. Holthusen. Ztschrft. d. Ver. deutsch. Ingenieure, 77: 37, 1013, September 16, 1933. Water furnished by new Curslack ground water supply of Hamburg is obtained from percolation of surface water over 5500-acre gathering ground, in which are located 272 tube wells, each with 55-yard protecting strip, which obtain their water from sand stratum about 40 feet thick whose upper surface is about 18 feet below ground level. Up to 29,000,000 gallons, or 60 percent of supply, are taken daily for percolation from the Elbe, the Bille, and a drainage ditch, and thus serve for replenishment. Only minor changes have occurred in the water during five years of operation. Temperature has risen from 9.2° to from 9.5° to 9.8°C. Bacterial count is usually 0, and always less than two organisms per cc. *B. coli* could not be detected in 1000 cc. portions. Iron, manganese, and carbon dioxide contents of water have recently increased, but increase has now ceased. Because of increased carbon dioxide content, de-acidification plant is being built.—*Manz. Translated by Selma Gottlieb.*

Influence of Rhine Floods upon the Water Works Wells of the City of Bonn. H. Selter. Ges.-Ing., 56: 24, 282, June, 1933. Bonn is supplied by two wells located 95 feet from the bank of the Rhine. Bank is well protected by a strong dike, but it is possible for flood water to enter soil at points about 325 to 500 feet upstream. Daily examination of water shows that total bacterial count increases at start of flood, but falls again to normal value three days later, without regard to duration of flood. Sudden rise of stream saturates upper layers of soil, previously dry, carrying bacteria through at first. As soon as soil is sufficiently damp, its filtering capacity becomes great enough to retain bacteria. The coli titer is more strongly influenced; that following incubation at 37° shows a greater and more lasting increase than that at 46°. The question, when to start chlorination, must be answered in each case by bacteriological examination.—*Manz. Translated by Selma Gottlieb.*

Practical Significance of the Clark Method in Drinking Water and Industrial Water Investigations. T. Wohlfeil and W. Gilges. Arch. f. Hygiene, 110: 2, 125, May 1933. Values obtained by the Clark method are increased by presence of much free carbon dioxide. In distilled water, increase of 100 p.p.m.

in carbon dioxide corresponds to an apparent hardness of 18 p.p.m. Acid sufficient to bring the pH to from 4.5 to 2.4 shows a CLARK value of 18 to 54 p.p.m., so that influence of pH as found in natural waters is negligible. Addition of alkali eliminates error due to carbon dioxide, small turbidity usually resulting being without effect. CLARK hardness values are higher than carbonate hardness and usually lower than total hardness values by BLACHER or WARTHA-PFEIFFER methods, but correlation is irregular and not predictable. Better correlation is found between CLARK values and carbonate hardness. Former cannot be considered as hardness values in the usual sense. Since other influences are included, CLARK method measures the foaming or soap-consuming power of the water, and should therefore be called foaming capacity. This is of value in addition to gravimetric and volumetric determinations, since neither of these latter gives a similar measure of soap consumption. In natural waters, only free carbon dioxide increases values appreciably, influence of other factors being unimportant.—*Manz. Translated by Selma Gottlieb.*

The Springwells Filtration Plant, Detroit, Michigan. E. A. HARDIN. Proc. Am. Soc. Civil Engineers, **60**: 1289, November, 1934. Plant is of rapid sand, gravity type, with ultimate capacity of 300,000,000 gallons daily, based on filtration rate of 180,000,000 gallons per acre daily. Total cost was $6,600,000. Experimental plant with capacity of 150,000 gallons per day was constructed in 1925 and upon findings from this plant the final design was based. Plant, which includes chemical plant, mixing chambers, settling basins, filters, office and laboratory building, and filtered water reservoir with capacity of 40,000,000 gallons, is described in detail.—*H. E. Babbitt.*

The Flow Net and the Electric Analogy. E. W. LANE, F. B. CAMPBELL, and W. H. PRICE. Civil Engineering, 4: 10, 510, October, 1934. Describes devices used by the U. S. Bureau of Reclamation for studying moving water. Principles of the flow net, which depend upon conceptions of differential calculus, have been used to solve a variety of problems such as: the magnetic fields surrounding the poles of an armature; pressure distribution in siphon spillways; the flow of water under roller dams; etc. Method seems first to have been introduced into this country by the late JOHN R. FREEMAN in *Hydraulic Laboratory Practice*, pp. 605–618. It is probable that first application of the electric analogy to solution of hydraulic problems was published by N. N. PAVLOVSKI. A more general conception of the flow net is sometimes called conformal representation, in which two families of curves, known respectively as the "stream" lines and the "potential" lines, are seen to intersect at right angles. The stream lines are conventionally represented by $\psi =$ a constant; and the potential lines, by $\phi =$ a constant. When plotted on the same sheet the lines form a grid of curvilinear rectangles. The respective equations of continuity of the two families of curves are

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} = 0 \quad \text{and} \quad \frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0$$

where x and y are the rectilinear coördinates. The flow net constructed graphically by a rather laborious procedure is identical with that obtained by resorting to the electric analogy. Experience with the electrical analogy apparatus has shown that potential lines can be located with a high degree of accuracy and that it possesses the very great advantage of permitting a solution of problems in three dimensions. A flow net used by aërodynamic engineers is developed by a method known as that of sources and sinks.—*H. E. Babbitt.*

The Tepuxtepec Rock-Fill Dam. A Major Flood Control and Irrigation Project in Southern Mexico. H. E. M. STEVENSON. Civil Engineering, 4: 10, 524, October 1934. Early in May, 1926, the Mexican Government began the greatly needed flood-prevention and irrigation development in the valley of the Rio Lerma, 120 miles southwest of Mexico City. Plan of the National Commission was to construct flood-control dam and storage reservoir and use the impounded waters to irrigate fertile agricultural lands in lower Lerma Valley. After study and investigation, steep, rock-filled dam, approximately 112 feet high above the base, with crest length of 900 feet, containing 91,000 cubic yards of rock and 17,000 cubic yards of concrete, was constructed. Storage basin is planned to contain 405,000 acre-feet, making 600 cubic feet per second available for irrigation.—*H. E. Babbitt.*

The Analytical Approach to Experimental Hydraulics. A Brief Résumé of the Mathematical Relationships Between Similar Systems of Flow. Civil Engineering, 4: 11, November, 1934. **On the Use of Dimensionless Numbers.** HUNTER ROUSE. 563. Not until the last decade did hydraulicians in general begin to look with great favor on the study of fluid motion through the laws of dynamic similarity and the use of dimensionless numbers. Originally the REYNOLDS number was applied to flow under pressure in smooth circular pipes, all of which, if sufficiently smooth, are similar geometrically. The FROUDE number applies in general to problems of rapid transition with free surface. The REYNOLDS number has been applied promiscuously to rough pipes, Venturi meters, orifices, open channels, weirs, spillways, etc., with viscosity apparently the sole criterion of variation in coefficient. FROUDE'S law and that of WEBER, on the contrary, through lack of the same publicity, have both failed to receive their just due in many cases and at the same time have been spared the embarrassement of frequent misapplication. Dimensionless numbers can be used effectively only by realizing the number of variables of which a phenomenon is a function and by taking steps necessary to investigate each independently. Any attempt to compare variation of weir coefficient with viscosity and capillarity will be inaccurate without due consideration of each factor independently. As an outstanding example of dangers attending general application of dimensionless numbers in interpretation of flow phenomena, attention is called to the Venturi flume with either floor, or side, contractions, a well-known form of discharge meter. As a warning, it is worth repeating following simple rule of dimensional analysis: if an expression is not dimensionally homogeneous, it is surely wrong; if an expression actually is dimensionally homogeneous, it may possibly be right. Di-

mensional Analysis in Model Studies. R. W. POWELL. 568. Dimensionless numbers ordinarily used in hydraulics are: REYNOLDS number, R; FROUDE's number, F; WEBER's number, W; and CAUCHY's number, C. Applying the theory of dimensionless numbers to model tests, it is evident that, since R is dependent upon viscosity, whenever variation in viscosity does not affect problem in hand, R cannot enter the result. If we may further assume that variations in surface tension and in modulus of elasticity are likewise without effect, then everything will depend upon F. The model must have the same F as the prototype. Since g (acceleration of gravity) is the same in both model and prototype, V (mean velocity over the section) will have to vary as the square roots of the dimensions. It is possible to represent completely the action of a very viscous fluid by a small-scale model using a fluid less viscous; but, unfortunately, water is one of the least viscous fluids. It seems generally true that as R becomes large, the functions involving it approach an asymptote. Hence, if a 1:100 model, then a 1:50 model, and then a 1:25 model are tested, a very accurate forecast of the values that would apply to the full-size structure can be obtained. The model should represent the prototype exactly to scale, including all the little projections and indentations which make up the roughness. Small-scale models should, therefore, be very smooth; smoother, sometimes, than they can be made. Limitations to small scales can be circumvented to a certain extent, at least in river work, by the use of distorted models. **Models Aid in Designing Irrigation Wasteway; Laboratory Tests Determine Construction Plans for Multiple-Weir Drop.** W. R. BARROWS and A. W. NEWCOMER. 595. Faced with the necessity of dropping 400 cubic feet per second of water 86 feet into the Rio Grande, the project engineers felt that neither an open, lined channel, nor a closed conduit, would safely handle the high velocities and absorb the great energy of the water. They designed a wasteway consisting of an open, lined channel, built on grade of approximately 12 percent and crossed at frequent intervals by weirs. To determine the shape, height, and spacing of the weirs, series of 20 models was tested in the hydraulic laboratory of the University of New Mexico. Article describes tests, states conclusions drawn from them, and explains such modifications of the design as were made during actual construction.—*H. E. Babbitt.*

Nomograph for Flow of Water in Cast Iron Pipes. J. R. GRIFFITH. Civil Engineering, **4**: 11, 601, November, 1934. A nomograph is given solving the WEGMANN-AERYNS formula,

$$V = 182.5\, R^{0.723}\, S^{0.539}$$

—*H. E. Babbitt.*

Forests and Stream Flow. W. G. HOYT and H. C. TROXELL. Trans. Am. Soc. Civil Engineers, **99**: 1, 1934. Effect on stream flow of changes in forest and brush cover on specific natural areas is described. An experiment by the U. S. Forest Service and the U. S. Weather Bureau was conducted from 1910 to 1926 on two contiguous tracts of land in Southern Colorado and stream flow measurements were begun in 1916 on certain areas in California, on some of which accidental denudation by burning afforded opportunity for comparisons not heretofore published. It is concluded: (1) forests do not conserve the

water supply; (2) increase in run-off is not wholly confined to flood periods; (3) where rain does not soak into the ground, flood peak for any small element of the drainage area occurs so soon after the storm that removal of vegetative cover has little effect on the time element; (4) the vegetative covering of forests did not, in the two areas studied, increase summer run-off, nor did it shorten the low-water period through the exercise of storage functions; (5) coincident with the increase in summer run-off, there was an increase in the average summer minimum and the period of low-water run-off was considerably shortened; (6) deforestation made no appreciable change in the low flows which occurred during the winter; and (7) erosion results from surface flow. In the Wagonwheel Gap area, there was practically no evidence of erosion after deforestation because there was little direct surface run-off either before or after deforestation. In the Southern California area, complete denudation increased erosion as a direct result of the increased surface run-off.—*H. E. Babbitt.*

Tests for Hydraulic Fill Dams. H. H. HATCH. Trans. Am. Soc. Civil Engineers, 99: 206, 1934. Derivation of formulas based on tests made for Cobble Mountain hydraulic-fill dam is given, as are also a consolidation study of core materials, a seepage formula for hydraulic-fill dams, and results of gradation tests of core materials of several such dams. Main object of paper is, however, to suggest standard tests for hydraulic fill dams.—*H. E. Babbitt.*

Foundation Treatment at Rodriguez Dam. C. P. WILLIAMS. Trans. Am. Soc. Civil Engineers, 99: 295, 1934. Design of foundation structure is described. Dam is of Ambursen type and is the highest heretofore built of this type.—*H. E. Babbitt.*

Study of Stilling-Basin Design. C. M. STANLEY. Trans. Am. Soc. Civil Engineers, 99: 490, 1934. Results of study, made by means of hydraulic models, to rationalize the design of stilling basins, one of the several devices used for prevention of scour at toe of dam. Relationships between the fundamental factors controlling the action of stilling basin are carefully compared and finally, a method of design based upon these relationships is presented.—*H. E. Babbitt.*

Model Law for Motion of Salt Water through Fresh. M. P. O'BRIEN and J. CHERNO. Trans. Am. Soc. Civil Engineers, 99: 576, 1934. In study of problem by means of hydraulic models, dimensional relations between model and prototype for similar flow were of primary importance. Investigation showed that a model geometrically similar to its prototype could not be used for a study of the relative movement of salt water and fresh water, but that model must be so distorted that scales for vertical dimensions, horizontal dimensions, and salinity satisfy a definite relation, namely $L_0 \div (d^{2.5} \times s^{0.5}) =$ a constant, in which L_0 is characteristic horizontal dimension of the model, d, its characteristic vertical dimension, and s, the salinity.—*H. E. Babbitt.*

Evaporation from Different Types of Pans. C. ROHWER. Trans. Am. Soc. Civil Engineers, 99: 673, 1934. The rate of evaporation from different types

of pans varies widely and before pan evaporation data can be used in estimating the loss from large bodies of water, it is necessary to know the ratio between the evaporation from the type of pan used and that from a large water surface, or else the relation between the evaporation from the pan and that from some other pan for which the ratio of the evaporation to that from a large water surface is known. Summary of results from available records is given, together with recommendations as to best types of pan to use under different conditions, and procedure to be followed in taking observations. Records from floating pans are not as consistent or reliable as land-pan records; nor is the evaporation from a floating pan any nearer the evaporation from a large water surface than that from a sunken pan of same size and shape.—*H. E. Babbitt.*

Evaporation from Reservoir Surfaces. R. FOLLANSBEE. Trans. Am. Soc. Civil Engineers, 99: 704, 1934. Results are given of 210 (all available) evaporation records in the U. S., in its outlying possessions, and in foreign countries, and are reduced to reservoir surface evaporation each by a stated coefficient. Relative effects of temperature, wind velocity, and relative humidity are shown by comparisons between pairs of records in which two factors are the same and the third is widely different. Brief discussion of the variation in evaporation throughout the U. S. concludes the paper.—*H. E. Babbitt.*

Standard Equipment for Evaporation Stations. Final Report of Sub-Committee. Trans. Am. Soc. Civil Engineers, 99: 716, 1934. Description is given of pans, essential equipment, auxiliary equipment and pan coefficients.—*H. E. Babbitt.*

High Dams on Pervious Glacial Drift. E. M. BURD. Trans. Am. Soc. Civil Engineers, 99: 792, 1934. Treats of matters of general design interest, such as foundation and embankment settlement, flexibility of structures, percolation, and spillway construction. Improvements and economics of design are suggested as necessary prerequisites to continued power development under existing natural conditions and economic limitations in connection with Hardy Dam on Muskegon River in Michigan. Coarse sand, gravel, or glacial mudstone, will support 13,000 pounds per square foot. Settlement is essentially proportional to load and takes place as load is applied. Sand embankments settle in permanent position when washed to place with water, but must be supplemented by impervious material. Such embankments can then probably be constructed for heads in excess of 100 feet.—*H. E. Babbitt.*

Actual Deflections and Temperatures in a Trial-Load Arch Dam. A. T. LARNED and W. S. MERRILL. Trans. Am. Soc. Civil Engineers, 99: 897, 1934. Four points are emphasized in layout and construction of the dam for Ariel Hydro-Electric Development: (1) design of the arch dam, effects of cement content and of manner and speed of construction on its thickness, and the resulting stresses; (2) proportioning of the concrete to secure good strength with a minimum of setting-heat generation; (3) amount of heat generated during setting and how it was dissipated; and (4) the radial and tangential

deflections of the arch. It was concluded that an arch dam may be constructed at high speed and the temperature of the concrete reduced to a suitable figure at the time of arch closure. The means of attaining this end are stated. Many other valuable conclusions are summarized.—*H. E. Babbitt.*

On the Behavior of Siphons. J. C. STEVENS. Trans. Am. Soc. Civil Engineers, 99: 986, 1934. Results of field tests of three siphons having nominal capacities of 100, 250, and 500 second-feet respectively, are presented. Important effects of cavitation are disclosed. Pressure gradients as well as pseudo, and true, energy lines are given. Simplified conception of action of siphons is presented, involving analogy to free flow and submerged orifices. Method of comparing siphons by standardized coefficient of flow and standard expression for efficiency of the siphon is offered.—*H. E. Babbitt.*

Stability of Straight Concrete Gravity Dams. D. C. HENNY. Trans. Am. Soc. Civil Engineers, 99: 1041, 1934. Necessity for abandoning the middle-third theory and the sliding factor as useful elements in masonry dam design is demonstrated. Safety of such dams is principally due to shear, and investigation is made of effect of loading on shearing strength. Résumé is given of available data on uplift pressure, with estimates of effective uplift area and of uplift force. Stability of dams of ideal triangular cross section is studied and a shear safety factor is proposed for use in dam design. The LEVY requirement is found to be excessive for dams less than 500 feet in height under most adverse conditions of uplift and more logical requirements fitting these conditions are suggested. Numerical examples are given of shear safety factors on the basis of cross sections of existing dams. It is shown that principles developed for straight concrete dams can be made equally applicable to other types of masonry dams.—*H. E. Babbitt.*

Duration Curves. H. A. FOSTER. Trans. Am. Soc. Civil Engineers, 99: 1213, 1934. Description of general properties of the duration curve, together with certain applications to hydraulic and water power problems. These curves are useful in statistical analyses and serve a purpose similar to that of the hydrograph and the mass curve.—*H. E. Babbitt.*

Water Supply Conditions in the Drought-Stricken Regions. O. E. MEINZER. Public Works, 65: 9, 19–20, 1934. Failure of surface supplies and of shallow wells has caused much trouble. Recognized water-bearing formations in general supplied the demands made upon them without serious depletion. Low ground water levels may be expected to continue until the spring of 1936. —*G. L. Kelso.*

Trends in Water Works Practice. PAUL HANSEN. Public Works, 65: 12, 53–54, 1934.—*G. L. Kelso.*

A Simple Chlorine Testing Outfit. FRANCIS E. DANIELS. Public Works, 66: 1, 14, 1935. Directions for construction of a small, portable chlorine testing outfit. Includes sketch and instructions for using.—*G. L. Kelso.*

Up-to-Date Carbon Control of Tastes and Odors. F. E. Stuart. Public Works, **66**: 1, 27–28. 1935. Carbon may be applied either by dry feed equipment provided with a water ejector, or by solution feed apparatus, or mixed with alum or lime. More recently it has been used in wash water for filters thus thoroughly impregnating the entire filter. Claims for this method of treatment are that the carbon particles stabilize the organic matter on gravel and sand and have great dechlorinating power.—*G. L. Kelso.*

Comparative Bacterial Efficiencies of Anthracite and Sand Filters. H. G. Turner, G. H. Young, and R. R. Cleland. Public Works, **66**: 1, 45–46, 1935. It has been shown experimentally that anthracite is superior to sand of same effective size and uniformity coefficient as a filter medium for removal of bacteria from coagulated waters. This is probably due to the angular shape of the anthracite particles in contrast to the rounded grains of sand. That bacterial efficiency varies with the degree of fineness of the filtering material was confirmed experimentally. Further experiments indicate that anthracite gives longer filter runs. Anthracite requires a slightly longer time than sand to reach its maximum efficiency, but at no time is its efficiency lower than that of the equivalent size of sand.—*G. L. Kelso.*

Pasadena's New Dam Dedicated: The Morris Dam. Water Works and Sewerage, **81**: 7, 233–234, July, 1934. Details given of location, cost, construction dimensions, and capacity.—*R. E. Noble.*

New York City Undertaking Extensive Pool Construction. Municipal Sanitation, **5**: 9, 309, September, 1934. Of twenty-three outdoor pools contemplated, nine are to be constructed immediately in congested areas to replace natural boundary waters destroyed for recreational purposes by pollution. Map shows (1) location of proposed pools, and (2) natural waters used for bathing, classified respectively as (*a*) fit, (*b*) questionable, and (*c*) totally unfit.—*R. E. Noble.*

Ferric Sulphate Coagulation. Philip J. Holton, Jr., and Elwood L. Bean. Water Works and Sewerage, **81**: 7, 229–232, July, 1934. Article discusses treatment at Providence, R. I., filtration plant with dry commercial "Ferrisul" (94 percent true ferric sulfate). Presented are, (1) factors in solution of ferric sulfate, (2) chart showing solubility curves for anhydrous ferric sulfate at various temperatures, (3) discussion on chemical feed and solution apparatus, (4) chart comparing results from use of three different coagulants, (5) table detailing cost of adapting dry feed machines for use in Ferrisul treatment, (6) chart showing effect of pH of filtered water on corrosion of pipe system, and (7) comparative data for copperas, chlorinated copperas, and ferrisul treatments.—*R. E. Noble.*

The Control of Swimming Pools. Carl A. Hechmer. Municipal Sanitation, **5**: 5, 156–158, May, 1934. Chlorine should be applied to filter effluent and pool water frequently tested for residual (*ortho*-tolidine method being simplest and most satisfactory). Joint Committee suggests that chlorine

residual shall not be less than 0.2 p.p.m., nor more than 0.5 p.p.m.: less than 0.2 p.p.m. will not insure complete sterilization, and with more than 0.5 p.p.m., complaints of irritated eyes, ears, and throat, or of chlorinous tastes and odors, will increase. To maintain this residual, chlorine dosage of from 1.0 to 1.5 p.p.m. may be necessary, depending on (1) patronage, and (2) water temperature. Outdoor pools are affected by sunlight and by pH variation. Inefficient filters will increase chlorine demand. Ammonia-chlorine treatment has been successful at some pools, ammonia being applied either as gas, through apparatus similar to chlorine machine, or in solution, as aqua ammonia. Ammonia must be applied before the chlorine and preferably in filter effluent, as 50 percent loss of ammonia may occur in passage through filter bed. Bactericidal action of chloramines (ammonia and chlorine in combination) is slower than that of chlorine; but they are more stable and maintain a more constant residual, rendering lower initial chlorine dosage possible. Chloramines are free from chlorinous taste and odor and from any irritating effect on ears, eyes, and throat. Their effectiveness against bacteria, however, becomes impaired when pH value is above 7.6. Being incapable of oxidizing nitrite, they are unable to prevent nitrite interference with the *ortho*-tolidine test, nitrites yielding with this reagent much the same color as chlorine. To overcome this difficulty, two samples are taken and in one of them chlorine is destroyed with sodium thiosulphate. Test both samples with the indicator and read after 15 minutes. Reading in de-chlorinated sample being that due to nitrite only, difference between the two readings will be the chlorine residual sought. Many pools report reduction in organic growths, algae, etc. with ammonia-chlorine treatment. Copper sulfate is also recommended to retard algae growth, but as excess copper sulfate may prove injurious to bathers, frequent treatment with small doses is advised, rather than occasional heavy doses. Treatment with from 0.3 to 0.35 p.p.m., or one-half ounce of copper sulfate per thousand gallons of water, three times weekly is usually effective; but higher doses may at times be necessary. Frequent chemical and bacteriological examinations of samples from inlet and outlet ends of pool should be made. Writer regards Joint Committee standard on bathing places as too lenient. With careful control, Treasury Department standards for drinking water can easily be met in pools. Mechanical apparatus for re-circulating system is discussed.—*R. E. Noble.*

NEW BOOKS

Report of the Seventh Annual Missouri Water and Sewerage Conference. Jefferson City, October 22–23, 1931. 6 x 9 inches. 84 pp. Sanitary Well Construction. A. G. Fiedler. 6–11. Location of wells should be considered in relation to (*a*) proximity of existing sources of pollution, (*b*) danger of flooding and (*c*) the character, depth, and water-bearing properties of the formations to be tapped. Type of well should be suited to location and to sanitary protection required. Wells should be adequately protected from surface contamination, usually introduced by drainage toward and into the well. Major defects which permit underground contamination are insufficient casing, defective casing, improperly seated casing, and defective sealing be-

tween casings of two sizes at their junction. Wells contaminated during construction should be chlorinated. Abandoned wells should be plugged. **Ammoniation: Topic of the Times.** H. S. HUTTON. 12–17. Ammoniation, properly done, will prevent formation of taste-producing chlorophenols, eliminate chlorinous tastes and odors, and permit carrying persistent residuals, guarding against contamination subsequent to treatment. Chemistry of the formation of mono- and dichloramines and their relations as affected by variations of alkalinity and pH values is presented. Ammonia should be applied before chlorine, and both in a manner that will insure rapid mixing through the entire flowing stream of water to be treated, and at a point that will allow ample time of contact for effective sterilization. **A New Plan for Financing City Improvements.** W. J. GRAY. 18–21. Constitutional requirement of two-thirds favorable vote on approval of bond issues for public improvements should be changed to simple majority. Changes are desirable in provisions for financing by taxbills. **Common Sanitary Defects in Missouri Water Supplies and Their Correction.** HERBERT BOSCH. 22–29. Defects common in both surface and ground water supplies:—cross connections, emergency intakes, open finished water reservoirs, and improper care of chlorinating equipment; in surface supplies:—lack of filtration, single filter unit, lack of gauges, controllers, and meters, and poor operation; in ground water supplies: lack of top seals on wells, undrained pump pits, insufficient casing, wells in broken limestone, water corrosive to casings, and dug wells. Program of correction started in 1928 is eliminating many of these hazards, so that 179 of the 200 municipal water plants in the State met the bacteriological standard in 1930. **The Construction and Use of a Floc-Detector.** E. E. WOLFE. 30–33. Of present available methods for determining need for filter washing, the BAYLIS floc-detector, home-made, is found to be best. Construction plan and specification are given. **Filtration Plant Problems.** L. O. WILLIAMS. 34–37. A variety of conditions contributing to unsatisfactory effluents are often allowed to continue by indifferent or untrained operating personnel. **Odor Control.** G. R. SCOTT. 38–42. In sewage disposal. **Sewage Disposal and Public Health.** H. C. DELZELL. 43–44. **Progress in the Treatment and Disposal of Human Wastes.** R. E. MCDONNELL. 45–51. **The Effect of the 1930 Drought on Public Water Supplies in Missouri.** W. S. JOHNSON. 52–63. 1930 drought in Missouri was fourth worst of record (since 1864). Detailed analyses, with tables and charts, show distribution of deficiency across the State for both precipitation and stream flow, effects on suface and underground water supplies, reservoir capacities indicated to be needed, and certain problems of water quality encountered. Lessons learned from this experience should be applied in protecting water supplies against the hazards of a recurrence. **Members of Conference, Superintendents of Water Works, Census of Water Supplies and Sewerage Systems, Ratings of Water Supplies, and Chemical Analyses of Missouri Water Supplies.** 64–80.—*R. L. McNamee.*

Report of the Eighth Missouri Water and Sewerage Conference, Sedalia, Missouri, October 13–14, 1932. 6 x 9 inches. 76 pp. **What Water Purification Operators are Thinking About.** C. A. SPAULDING. 5–12. Probable

saving of 350 lives in Springfield since 1912 by water purification is estimated to have money value of over $5,000,000, several times the cost of the plant. Each 5 p.p.m. of hardness depreciates the value of water $5.00 per m.g. Odors, tastes, and other unfavorable qualities are evaluated. Threshold method of odor determination is described. **When and How to Wash a Filter.** A. V. Graf. 13–17. Need of washing is variously determined: by fixed periods, by certain loss of head, by loss of head and limit of run, by controller reaching wide open position, by turbidity of effluent, or by the manner of operating the plant, as filtering in daytime, washing at night. Significance of these various indices is pointed out. Detailed directions for washing filters and observations to be made during washing are discussed. Sand expansion gauge is described and sketched. **Bacteriological Laboratory Control.** H. O. Hartung. 18–19. J. P. Smouse. 19–21. Constant vigilance by bacteriological analyses at various stages during treatment and distribution insures safe water to the consumer. **Chemical Laboratory Control.** R. C. Higgins. 22–23. Accurate daily records of chemical analyses of raw and treated water provide means by which chemical dosage may be regulated economically, over- and under-treatment avoided, and finished water of uniform quality produced. **Activated Carbon Treatment.** F. E. Turner. 24. Activated carbon fed dry with lime at mixing chamber at rate of 0.1 grain per gallon at cost of $1.57 per m.g. of water treated eliminated all taste and odor at Cameron, Mo. Carl Haynes. 24–25. At Moberly, Mo., feed rate of 0.04 grain per gallon eliminated foul and fishy odors from filters. **Prechlorination.** Cleo Brown. 26. At Harrisonville, Mo., prechlorination in mixing chamber to leave residual of 0.1 p.p.m. at filters, followed by postchlorination in clear well to leave residual of 0.2–0.3 p.p.m. produces a safer and more palatable water, saves alum, and keeps basins free of algae, and sludge less septic, reducing number of cleanings. **Zeolite Softening of a Well Water Supply.** A. W. Kirby. 27–32. Well water at Marshall, Mo., with hardness averaging 14 grains per gallon, is softened to zero and then mixed with unsoftened water to produce a resultant hardness of 3 grains per gallon and delivered to consumers at a cost for salt of $1.46 per 1000 gallons. Objections to change in taste were voiced at first, but soft water is now favored. Plant consisting of two vertical 8 feet dia. x 18 feet high units, each with capacity of 200–400 g.p.m., cost $35,000 for equipment, $13,000 for building. **Results from a Small, Inexpensive Iron Removal Plant.** E. S. Flannery. 33–34. Simple aërator, settling basin, and filter, with nominal capacity of 75 g.p.m., built at cost of $1650, successfully removes iron at Platte City, Mo. **Determining the Proper Water Rates for Smaller Communities.** R. E. Duffy. 35–39. No element of cost of producing water should be overlooked in determining basis of revenue. **Water Service Materials.** W. B. Rollins. 40–42. Copper service pipe is flexible, resistant to corrosion, galvanic action, electrolytic action, and frost, and costs less than any other complete service except galvanized iron pipe with lead gooseneck, with which it is about on a par, and which it will outlast about three times. **Routine Inspection of Fire Hydrants in Preparation for the Winter Season.** W. H. Henby. 43–47. Common causes of hydrants being out of service: damage to stems by unauthorized operation, injury by traffic, and freezing of water in barrel. Hydrants should be inspected before

each winter, all defects remedied, and all operating elements greased and left in good order. **Economy Derived from Proper Selection of Pumps.** H. C. HENRICI. 48–52. Considerations of efficiency and of type of service rendered by plunger, centrifugal, rotary, and air-lift pumps. **Painting Standpipes and Elevated Tanks.** H. E. NEWELL. 53. Tanks should be inspected for need of painting every two or three years. Thorough cleaning is essential preliminary to painting. **Method of Preparing and Collecting Water Bills.** W. E. BARNES. 54. Liberty, Mo., uses post card bills, which, when divided, serve as consumer's receipt and office memo. **Recent Developments in Sewage Treatment.** G. R. SCOTT. 55. **Laboratory Control of Sewage Treatment Plants.** R. E. FUHRMAN. 59. **The Collection of Gas for Heating Sludge.** G. S. RUSSELL. 61. **Prechlorination of Sewage for Odor Control.** G. C. FOX. 63. **The Power Cost of Activated Sludge Treatment.** H. BROWN. 64. **Census of Water Supplies, Sewage Treatment Plants and List of Water Works Superintendents in Missouri.** 65–73.—*R. L. McNamee.*

Proceedings, Sixth Annual Meeting, Kentucky-Tennessee Section, American Water Works Association, Nashville, Tenn., February 5, 6, 7, 1931. Mimeo. 8½ x 11 inches. 106 pp. **Addresses.** H. E. HOWSE, W. S. PATTON, DR. E. L. BISHOP, G. H. FENKELL, B. C. LITTLE. **Stream Flow Records and Their Relations to Public Water Supplies.** W. R. KING. 13–25. Source and character of surface and underground waters of each part of Tennessee are described. Surface waters as sources of public water supplies have the advantages that quantity available can be readily determined, sources of pollution are easily located and remedied, and water is generally soft and of good quality; they have the disadvantages of wide range of turbidity, that treatment is usually necessary, that fluctuation in river stage complicates plant construction, and that temperature rises during the summer. Ground waters have the advantages of being free of suspended matter, of having fairly constant pumping heads, of being less liable to pollution, and of having more uniform temperature; they have the disadvantages of being generally hard, of uncertainty as to available yield, of high lifts from deep wells, of difficulty in locating and remedying sources of pollution. **Modern Methods of Cleaning Filter Sand.** C. V. SWEARINGEN. 25–30. Preliminary to actual cleaning operations, laboratory tests showed that HCl and H_2SO_4, as weak as 5 percent, removed organic matter and manganese very well; HNO_3, 25 percent, cleaned fairly well; $CuSO_4$, 5 percent or 15 percent, chlorinated lime in saturated solution, and caustic soda, 5 percent, 10 percent, or 15 percent, did not clean sand. In plant scale operations, 5 percent H_2SO_4 cleaned 27 cubic yards of sand coated with organic matter and 48 cubic yards of sand coated with manganese, from open gravity filters, in 40 days at a cost of $438.10. Organic matter removed amounted to 25 percent of original volume of sand. Of sand from closed-type steel filters, 213 cubic yards were cleaned by jetting to washing box and returned to filters at cost of $1.95 per cubic yard. **Comparison of Chemical and Hydraulic Methods of Cleaning Filter Sand.** H. A. GUY. 30–37. In 1929, 12 gravity filters at Nashville, Tenn., were cleaned by 2 percent caustic soda bath followed by high pressure hosing; 80-cubic-yard units were cleaned at cost of about $75 each, including wash water. In 1930, same filters were

again cleaned, each unit only receiving 12 hosings (½-inch nozzle, 130 pounds per square inch pressure) at cost of $43 per filter, during a total time of 47 days. **The New Water Supply Unit at Dyersburg, Tenn.** S. R. BLAKEMAN. 37–41. Description of difficulties in securing surface or well water, solved by installation of gravel-wall type well. **Distribution.** H. C. BRISTOL. 42–47. Recommendations and advice on installation of pipe distribution systems. **Valuation and Rates as applied to Water Utilities.** M. R. WILLIAMS. 47–56. Determination of proper value to be used for rate base should be founded upon fair consideration of historical cost, original cost, and cost of reproduction. Discussion concerns depreciation and setting up of reserves therefor. **Meter Rates as compared to Flat Rates as a Revenue Producer.** G. B. SHAWVER. 56–61. Sale of water by meters is beneficial to water plant through reduction of waste, and fair to the consumer by allocating charges in proportion to use. **Emergency Water Supply for Lexington, Ky., from the Kentucky River.** G. S. BELL and CLARK CRAMER. 61–69. Description and chronology of construction operations involving 6¾ miles of 20-inch cast iron and steel main, two electric substations, 10½ miles of electrical transmission lines, and a 4-m.g.d. 500-foot head pumping station, at a total cost of $300,000, between adoption of plan on September 26 and placing plant in service on December 10. **Effect of the Drought on City Water Supplies in Kentucky.** R. R. HARRIS. 69–73. Notes concerning the low rainfall of 1930, 27.55 inches, about 60 percent of average, and its effect upon the water supplies of, and remedial measures applied at, Shelbyville, Richmond, Lexington, Lawrenceburg, Lancaster, Greenville, and 26 other towns. **The Drought and Peak Loads.** W. H. LOVEJOY. 74–77. Comparative study of precipitation, temperature, and average daily, maximum daily, and maximum hourly pumping rates at Louisville, Ky. **The Use of Ammonia-Chlorine Process in Water Purification Plants in Kentucky and Tennessee.** A. E. CLARK. 78–87. At Danville, Ky., ammonia-chlorine, ratio 1:2, eliminated taste and odor from vegetable decomposition and eliminated algal growths from basin walls. At Lexington, Ky., ratio 1:3 allowed chlorine dose to be reduced 40 percent and still leave same residual. At Jackson, Ky., ammonia-chlorine, used for a short time, was apparently successful in removal of chloro-phenol taste due to wood distillate waste. At Nashville, Tenn., ammonia-chlorine prevented bacterial growths, but effectiveness in algal control and taste and odor removal was not definitely demonstrated. At Knoxville, Tenn., ammonia-chlorine effected taste elimination, partial inhibition of algae, decrease of loading on filters, safer filter effluent, and lightening of burden on final chlorination. Discussion discloses results, successful and otherwise, and indicates need for more careful experimentation. **Facts concerning the Origin and Evolution of the Nashville, Tenn., Water Works Department.** R. L. LAWRENCE. 88–100. Historical notes, 1806 to date, concluding with description of new 28-m.g.d. filtration plant. **Building up a Run-down Water Works under a City Manager.** J. F. KINGSLEY. 100–105. Intimate details of shortcomings discovered and improvements made in reorganization of Covington, Ky., Water Department. **Resolutions.** 106.—*R. L. McNamee.*